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General Sessions

The Future of the Sugar Beet

W. W. ROBBINS[1]

In his excellent article entitled "The Sugar Beet: Product of Science," published in the Scientific Monthly, March, 1949, Dr. George H. Coons has a summarizing section in which he says, "The sugar-beet industry is now faced with economic problems that threaten its survival."

This is a thought-provoking and quite conservative statement. It deserves further consideration by the members of The American Society of Sugar Beet Technologists. "It is possible that the future status of the industry will depend, at least in part, on the combined and varied researches of a group of workers such as here assembled. And, it is not improbable that, in spite of technological progress in the culture, processing and utilization of the sugar beet, the economic and political turn of events in the world may decide the ultimate status, if not the fate, of this important crop plant. In these times we frequently observe that technology, economics, sociology, and politics are working at cross purposes."

The future of sugar is secure. This is self-evident. Sugar is basic in our whole economy. There is no substitute. It is a food. It is fuel. It is a foundation chemical in the manufacture of innumerable industrial products. As stated by Dr. R. C. Hockett of the Sugar Research Foundation, "sugar is the largest dry cargo in international trade—the only pure organic chemical which has a tonnage production in the United States in excess of 14 billion pounds annually." Without doubt the total use per capita of sugar in the world will increase. Whereas the annual consumption per capita in the United States is around 100 pounds, there are millions of people with a yearly consumption well below 50 pounds. These peoples constitute a potential market.

Sugar needs less defense than does the beet as a source of sugar. Let us not worry too much over the fact that some few in the medical world are telling parents to give their children less sugar because of its injury to teeth. Such considerations are mere trifles and have little bearing upon the future of the sugar beet.

Man has become increasingly energy-conscious. Material progress down through the years has depended upon the harnessing and transformation of energy. Coal and oil, fast dwindling, have been our principal sources of energy for industrial development. Man-power, horse-power, ox-power—these represent the energy derived from foods. The energy in foods is transformed solar energy. We speak, move and think. These processes require energy. The food we eat is the source of this energy. We are re-evaluating crop plants in terms of calories, i.e., energy. We have witnessed recently an earth-shaking step—the fission of the atom—in which prodigious quantities of energy are liberated. The efficiency of all machines and operations is an energy-relation. Victory goes to the combatant who has the largest stores of energy and utilizes them with the greatest efficiency. Wars are fought to secure access or control of coal, oil and rich agricultural lands—all potential

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sources of energy. In the struggle of humans for existence, in a world whose population is increasing at a more rapid rate than food production, the fight will increase in intensity for basic energy-yielding materials. There is a philosophical implication, with increasing import, which may be stated as follows: The waste of energy in any form is the very essence of evil; its conservation the essence of good.

Living organisms—all plants, both green and non-green, and all animals, including man—need a continuous source of energy. Except a few special types of bacteria (chemosynthetic organisms), this energy is derived directly from the oxidation of foods, the carbohydrates, fats and proteins. Foods are organic substances manufactured from inorganic ones by green plants, and only green plants. The raw products in the manufacturing process are two low-energy compounds, water and carbon dioxide. In the cells of plants which possess a green pigment, chlorophyll—water and carbon dioxide are chemically united to form a simple sugar, a relatively high-energy compound. The chemical reaction, that is, the combining of water and carbon dioxide to form a sugar, requires energy. This energy is that from light; it is solar or radiant energy. Chlorophyll absorbs the light energy, and in some manner not understood, it becomes available to the cellular protoplasm, and is utilized in the work required to bring about the synthesis of a sugar from water and carbon dioxide. The sugar molecule represents a supply of energy —chemical energy, transformed solar energy. The process of converting solar energy into chemical energy by chlorophyll-bearing plants is known as photosynthesis. We may well regard photosynthesis as the world's most important chemical action. All the carbon in plants and animals is derived from the CO_2 of the atmosphere in the photosynthetic process.

For millions of years this energy conversion by green plants has been going on. The energy in coal, petroleum, oil shale and natural gas, appropriately called "fossil energy," represents the energy of light which fell upon green plants which clothed the earth ages ago. Photosynthesis is a process which changes solar energy to forms of energy usable by plants and animals as food, and as fuel for industrial development. It seems that we have been slow in realizing how strict our dependence is upon the sun as the great source of energy. Farmers, primarily the growers of green plants and of animals which live on green plants, constitute a group in our world economy which produces the only living organisms possessing the power of converting solar energy into the potential energy of organic compounds. This is no mean responsibility. It gives support to the campaign orator speaking to a rural audience when he says, "The farmer is the backbone of the country," but it is doubtful whether he understands the full meaning and basis for the statement.

In the temperate zone about 7⅓ billion kilocalories (1 kilocalorie is 1,000 calories) of the sun's radiation come to each acre of land or water surface per year. This is approximately 20 million per day or about one kilocalorie per square foot per minute. In the Tropics this figure is greater, and, moreover, the growing season is longer. Spoehr states this in a different form when he says that "The solar energy received on an acre of land during a growing season of 90 days is equal to the energy contained in 243 tons

of anthracite coal." Wigner asserts that "The total amount of coal under the ground in the United States has somewhat less heat content than the United States receives as sunshine during a single year."

Unfortunately, the green plant is a very inefficient machine in its transformation of energy. Its efficiency has been measured in various ways. An acre of Wisconsin aspen trees produces in a year about 2 tons of wood. When these 2 tons of wood are burned, 8½ million kilocalories are yielded. This represents somewhat less than 1/10 of 1 per cent of the total solar energy which fell upon the acre during the year. Transeau calculated the efficiency of photosynthesis in corn. He considered an acre of corn growing in north-central Illinois and yielding 100 bushels during a growing season of 100 days. Taking the grain, leaves and roots, he calculated that the corn plant used about 1.6 per cent of the available solar energy. The harvested grain alone represented about 0.4 per cent of the total radiant energy which fell on the acre during the 100-day growing period.

Suffice it to say that green plants, including crops, utilize but an extremely small fraction of the total solar energy coming to the area upon which they grow.

In spite of this low efficiency of energy-conversion by plants, the annual total world production of the products of photosynthesis amounts to something over 2,000 times the yearly production of steel, which is 100 million tons. Schroeder estimates that the green plant life of the world's land area of 37 billion acres fixes about 18½ billion tons of carbon per year.

Logically, we come to the following significant question: What is the relative efficiency of various crop plants as converters and storers of solar energy? If certain ones are more efficient than others, then it follows that these should be given some priority in our agricultural planning. Moreover, a crop which yields by-products capable of being utilized as a source of energy warrants more favorable consideration than one whose by-products are non-utilizable.

Various methods have been employed to measure the energy-value of the major crop plants. For example, Monier Williams gives the yield in gallons of 95% alcohol in the following crops: Rice 44, wheat 50, barley 59, corn 72, potatoes 164, sugar cane 306, and sugar beet 353. As with sugar cane, potatoes, corn and other cereals, the sugar beet ranks very high as an efficient converter and storer of solar energy. This relatively high efficiency, duly recognized, should firmly establish the sugar beet in our economy—in a world in which energy in every form is becoming increasingly critical and vital.

Today the most unexpected discoveries in science may occur. They come upon us in rapid succession. How many of us ever dreamed a decade ago that man would be able to bring about the fission of the atom, and utilize the energy wrapped up in that infinitesimally small particle? In other fields, how many of us anticipated two decades ago how drastic the changes would be in our economics, sociology and politics, both national and international?

Let us discuss for a moment the various changes which could affect the

status of the sugar beet industry. Research on the fundamental process of photosynthesis is now active in about a dozen laboratories. Biochemists are of the opinion that there is no theoretical reason why the synthesis of a simple carbohydrate cannot be done. Suppose we engaged a group of several hundred qualified research workers, and provided them the sum of 2 billions of dollars, an amount expended on atomic research, it is not unlikely that a way would be found to do in the laboratory and factory what is now accomplished in the green plant. Daniels states: "If some one had asked me to guess ten years ago which would come first, atomic energy or photosynthesis without the living plant, I would have guessed the latter." Suppose it becomes possible to convert solar energy into the chemical energy of the sugar molecule so cheaply that we could use sugar not only as food but as fuel. If these technical discoveries come to pass, undoubtedly they would have a profound effect on the sugar industry.

The population of the world is increasing rapidly, an increase unfortunately uncontrolled. This will affect land utilization, international relationships and agreements, and intensify the struggle for sources of energy. Who knows what these relationships and agreements in the years ahead will bring? In truth, the fate of the sugar beet depends greatly upon the turn in international relationships, and the relative strength developed by conflicting social and economic ideologies. Suppose the present trend which started in the early 30's in the United States toward a controlled economy, and in other countries somewhat earlier, with its acreage and production allotments by geographical areas, its price controls, its subsidies, and what-have-you, continues, we may have the experience of seeing economists in certain high places saying to those sugar beet growers in areas where yields are comparatively low: "Do not grow sugar beets. It is to the best interest of our whole economy that you grow wheat or corn or flax." Or they might say: "We in the United States should grow no sugar beets. Sugar should be produced in the tropics."

The exploitation of tropical areas is bound to occur. Salter estimates that a "total of one billion acres of tropical and subtropical soils may be used in calculating world soil potentialities." There is progress in the control of tropical diseases, and general improvement in living conditions in the tropics, both of which will tend to attract capital investments to these areas. Moreover, tropical agriculture is becoming mechanized. These changes may bring about a phenomenal increase in sugar cane production—a development which would undoubtedly react upon the status of the sugar beet. Particularly would this be the case should extant theories laying stress on the economic use of the world's land areas be put into effect.

There is serious discussion in the world about the race between population and food supply. Production, distribution and use of food have become a main concern in a world whose population is increasing rapidly, and even now sees one-half of the world's peoples on a sub-standard nutritional level. Dr. H. R. Tolley, director of economics and statistics, Food and Agricultural Organization of the United Nations, estimates that food needs in 1960 will call for a 12 per cent increase in sugar production for the world

as a whole in order to bring nutrition to the levels assumed to be necessary. The greatest needs will be for milk (100% increase) and meat (46% increase). Apparently, the bottle-neck in the world food situation is protein shortage. Peason and Harper estimate that, of the total food consumed by the world's population, grain and grain products make up 73% (dry basis), vegetables and fruit, 12%; sugar, 6%; and all animal products, 9%. It is of interest to note that the proportion of total human food derived from animal sources varies greatly in different areas of the world. For example in Asia it is 3%, Africa 4%, South America 16%, Europe 17%, North America 25% and Oceania (including New Zealand and Australia), 36%.

Based on the estimated food needs of the world in 1960, it is believed that the requirements can be met for sugar, and for roots and tubers, and probably cereals, by proper management and utilization of present farm lands. This supposes a stepup in erosion control, in plant breeding, in use of fertilizers, in control of insects, plant diseases, and weeds, in mechanization, i.e., in technological improvements. The other classes of foods will fall short of needed production, unless extensive new land areas are brought under cultivation.

It is well understood by the members of this Society that in judging the value of the sugar beet industry to a community indirect benefits as well as direct ones must be considered. "The culture of sugar beets in a district raises the standard of all agricultural methods and increases the stability of agriculture in the entire district. The successful culture of sugar beets is not consistent with poor farming. It is a culture which requires thoroughness, and sooner or later this is reflected in the growing of other crops. Without reference to sugar as such, beet culture is for many reasons essential in intensive agriculture. And then of major importance is the fact that the sugar beet, considering not alone the sugar, but the by-products, is a relatively efficient converter and storer of solar energy. This is a basic consideration."

Looking ahead to the world food needs in 1960, foods rich in proteins appear to present a particularly serious problem. By virtue of its important role in supplying by-products which foster the livestock industries, the sugar beet occupies a favorable position. This situation emphasizes strongly the urgency of complete and efficient use of all sugar beet products. By so doing, we can place ourslves in a favorable position in any agreements as to the relative merits of the sugar beet and sugar cane. But, these are facts not fully understood and appreciated by those who may have influence in shaping the destiny of the sugar beet industry in this country. It seems obvious that the membership of this Society has a responsibility here. Our most effective propaganda will be technical progress leading to higher yield, lower costs, more complete use of by-products, and more emphasis on all the indirect benefits of the crop. We must have stands of beets which will capture a maximum amount of the radiant energy that comes to a unit area. We must be conscious of the fact that there is a very basic reason for the complete utilization of all by-products. Let us not forget that potential yields are far below the average; that the discrepancy between maximum yields and average yields in every beet territory is far too great.

We have made progress. With this you are familiar. Surveys in certain territories show that the man hour requirement to grow and harvest an acre of sugar beets dropped from 120 hours in 1915 to 66.85 hours in 1948. In field and factory, from seed bag to sugar bag, there has been progress and increased efficiency. Geneticists, agricultural engineers, plant physiologists, entomologists, botanists, plant pathologists, chemists, factory operators—in fact, technicians of every sort have made their contributions. These are the individuals who make the American Society of Sugar Beet Technologists.

It behooves the American Society of Sugar Beet Technologists to continue in its efforts to increase the efficiency of the sugar beet industry. I speak of efficiency in the fundamental terms of energy transformation. This energy transformation begins with the first expenditure of human energy and the energy set free in the combustion of gasoline during preparation of the seed bed. It proceeds throughout every operation in the growing, harvesting, processing and marketing of the crop. Our continued usefulness in the economic scheme of things, and it may be our survival, depends upon an increasing efficiency in this transformation of energy from bag of seed to bag of sugar. The industry will experience ups and down as in the past. But, if we do our part, final judgment will be a general and widespread vindication of the sugar beet. The direction taken and the quality of our technological researches will go far in maintaining and improving the status of the sugar beet in American agriculture. It is not the primary function of this Society to propagandize. Rather, we must furnish the ammunition to be used by the proper individuals and organizations who believe in the sugar beet and are working in its behalf.

The sugar beet industry is no longer an infant. It is now a fairly strong and more or less independent young man. In spite of the usual troubles which all infants experience, and at times improper and inadequate nourishment, the child has grown and attained an age past adolescence. Its parents were of the sturdy pioneer type who believed in free enterprise. They nurtured and cared for the child in much the same way as did the great and great-great European grandparents. Doctors did not always properly diagnose the ailments nor give satisfactory treatment, due principally to inadequate knowledge. Then, too, the environment in which the child developed was at times difficult and unpredictable; there were some bad boys in the neighborhood, and the parents of these boys sometimes had little sympathy with the young fellow. In fact, they had no use for him, and would, if they could, banish him from the community. The young man now finds himself in an environment where controls prevail; his behavior is carefully scrutinized both by his neighbors and his parents. The money he earns and spends and saves is under strict supervision. Sometimes his ambitions are thwarted, and his plans for the future dashed liberally with cold water. Yes, our youth entered college. His curriculum was a stiff one. He had many things to learn—engineering, agronomy, chemistry, entomology, plant pathology, genetics, soils, and even weed control. Sometimes funds were low, and his studies suffered. Tuition fees were raised. He entered the army, and we believe his services were a credit to the country. Orders from headquarters were frequent and often confusing and conflicting. But he

came through the conflict with only minor wounds—but no Purple Heart.

Yes, our infant is now a young man. For his age, he is experienced, fairly strong and energetic, and has attained a state of precarious independence. He has both friends and foes. Most certainly, his education is not complete; he must always remain a student; he must improve his working methods and habits; be progressive, efficient, frugal, and even conscious of his obligations to the complex and changing community life and world in which he finds himself. He must, in fact, carve out for himself a career in this complex world of conflicting ideologies which will make him an indispensable man.

Men of Faith[1]

GEOFFREY S. CHILDS[2]

As president of the Farmers & Manufacturers Beet Sugar Association, in whose area you are meeting, I first of all want to extend to the Society a very warm welcome and the hope that your deliberations will be thoroughly successful. Looking over this program I don't see how these meetings can be anything but successful, unless perhaps it leads to some sort of mental indigestion. But that can be overcome by a certain amount of frivolity which I assume goes along with all sugar gatherings. The two have to be kept in balance some way and that is your problem. In any event, we do hope that you will enjoy yourselves here in every way. We are delighted to have you meet in our area.

My subject is "Men of Faith."

I am going to open by reading to you an excerpt from that great book of Fred Taylor's, "The Saga of Sugar," which I believe every sugar man should reread from time to time just to realize what it means to be a sugar man:

> "It is difficult to exaggerate the importance of the contributions of some of the individual pioneers to the sugar factory project. One Phillip De LaMare, who captained the wagon trek of the machinery across the Great Plains, was a young man of only 29 years and reared in the luxuries of civlization. It is doubtful if there is another episode in the industrial development of America which for sheer courage, stamina and physical endurance surpasses the story of De LaMare and his party.
>
> "Says De LaMare—
>
> " 'I saw a task before me that seemed almost beyond the power of man to accomplish. One thousand miles of uninhabited country lay before me, and beyond rose great chains of almost unexplored mountains.
>
> " 'On July 4, 1852, the long trek began. Only four or five miles were covered the first day and with the trip hardly begun, those miles brought forth the greatest of all of their calamities and disappointments. Some of the wagons carried from 5,000 to 9,000 pounds, requiring four to eight oxen each to pull them, and they had been especially constructed to withstand the heavy loads. Now it developed that they were very badly made with faulty green timber. Axle-trees broke on many; others gave evidence that they could not stand the trip. It was tragedy.
>
> " 'Now out of funds, yet with characteristic courage and determination, De LaMare set forth to obtain more wagons. By dint of great persuasion and at the cost of considerable time, he managed to obtain on credit some 40 Santa Fe wagons—this time the best of prairie schooners.
>
> " 'Out into the great uninhabited plains they traveled. Each day they drew further and further away from civilization. Days and weeks and months passed and still they pushed on'."

Well, then the story goes into more and more trouble and finally it says that:

> "In early November of 1852, more than four months after leaving Fort Leavenworth, these weary travelers reached Salt Lake City. Only by their great ingenuity and overcoming almost insurmountable obstacles; only by their great resourcefulness and stamina and only thru the great leadership of De LaMare did these men bring their expedition thru to success."

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[1]Address delivered to the general meeting of the American Society of Sugar Beet Technologists, Detroit, Mich., Feb., 1950.

[2] President, Michigan Sugar Company.

Ladies and gentlemen, that story is really the story of the sugar industry itself. This industry is characterized by men who *work* and *love* their work; and as one who has been privileged to spend 16 years in the sugar beet industry (which is but a day), I want to pay tribute to all sugar men, high and low, who are worthy of the name. I know of no group of men who seem to better typify that something which to my mind is the greatest thing there is, and that is men who really *work* and who *love* their work and who, therefore, make possible all the things that we have.

When we talk in generalities like this, we pose to each individual one of us the question as to how we are fitting into that splendid picture of the men and the industry we admire so deeply. So I want to talk to you for awhile about the job that confronts us. My thought is to treat the subject first from the standpoint of management (which happens to be my particular part in the situation in this area); and, secondly, from the standpoint of your and my responsibilities as individuals.

First of all, I think one of management's great responsibilities is to be constructive. Management must see to it that the industry is sound and profitable because, if this industry is not well managed, then all the work that we as individuals do will go for nothing. Without any desire to point a finger, I would say that there are times when management has not been too constructive and I think this fact should be recognized as a truth.

It is a responsibility of management to encourage real cooperation. One of the stumbling blocks of this industry has been the fact that there is a tendency for great loyalties to divisions of the business. You have the men in agriculture devoted to agriculture and all problems concerned therewith but who display no great interest in processing, selling or accounting. In other words, there is a feeling that their side of the work is the all in all. Of course, without the raw product, there isn't any processing. But the fact remains that, unless the agricultural division works with the processing side of the business, there is conflict and there is a lack of the real harmony which leads to good results. Now, this matter of cooperation cannot be brought about by just talking about it or thinking it is a good thing. It is management's responsibility to see that the agricultural division of the business, the processing division, the selling division and the accounting and financial division of the business are guided and inspired to work in real harmony.

I think another great responsibility of management is to provide and build new leaders. This industry has suffered from the gap between top management and the men qualified to take their places. There is no sound constructive management where there are not being developed capable, trained, ambitious, conscientious younger men to take responsibility and to prepare for real leadership. And so I say to you that, in every division of this business, there should not only be capable men who are now in charge of every phase of it but directly under them thoroughly competent men (and I would say college-trained men), ready to step in as the necessity arises.

This industry has in the past been built by men, in many cases, who "just grew up" with the business. That was all right for that era. But that isn't enough for this era. This era calls for constructive men, college-trained men, and so I say again that one of the great responsibilities of management is to see that those men are provided.

Another great responsibility of management is to encourage research. We can take satisfaction in the realization that that necessity has at last come to be recognized. I think the American Society of Sugar Beet Technologists is doing yeoman work in the field of research. Then there is the Beet Sugar Development Foundation, as a clearing house of research, in the western area. These groups are supplemented by research activities on the part of associations and companies in the industry. One of the great goals of this effort is to increase the yield of sugar per acre. Dr. Robbins was telling me about a chart out in the hall, which shows what has happened in California, where beginning in 1925 the average yield per acre has risen steadily until now it is around 19 tons per acre. Of course, in California they do everything in a big way. We may not be able to equal that figure but we can approach it. Seriously, we do know that there is available knowledge today that if put into effect will increase the average yield in any territory. A further contribution to research work is the Sugar Research Foundation, which is engaged in fundamental research dedicated, among other things, to the discovery of new uses for sugar and its by-products.

There is a tremendous field, in my opinion, for the discovery of non-edible uses of sugar that would tend to offset the danger of producing too much sugar with the resulting demoralization of prices both in this country and in the world as a whole. I also feel that there are important new uses for our by-products that will affect their value favorably.

Of course, research must also be concerned with the opportunity for reducing costs by the discovery of better methods of processing.

Well, the good thing about all this is that there are in effect, as I have said, research groups now struggling intelligently with all of these problems and beginning to show some results.

Let me add that I think it is also the duty of management to think in terms of what can be done to increase the goodwill of this industry. We have suffered, for reasons that we don't need to go into here, from a lack of goodwill. Part of that lack of goodwill has been definitely encouraged by various and sundry forces, but certainly this industry would profit if we could find an intelligent means of increasing the public goodwill towards the industry.

Now, may I digress for one moment to say this: You have all heard that we should find uses for our factories in non-operating seasons. Well, maybe we should. There are some attempts being made here and there. I am not too sure that this is a good idea or a sound one. In other words, outside of the sugar equipment, all we really have in these beet factories is a power house. You can't convert a sugar house into some other basic use and not put in entirely new equipment if you are going to do a competing job. We have a power house that could be used and you might have a

situation where you could use your field force in connection with some agricultural development, but I just want to make one little observation. There have been some noble experiments in trying to use sugar plants for other purposes that have turned out rather disastrously. Why? Because there is a genius that goes with each business. Why don't we make candy? Why don't we become bakers? Why don't we make everything our product is used for? Because that isn't our genius. The great danger of getting caught up in this idea of trying to fill this so-called seasonal gap with some other business activity is the danger of neglecting your basic activity. That statement is open to challenge and I may be all wrong. But I mention it as perhaps a little comfort to some sugar people who are hearing from time to time how we only operate three or four months of the year. Are any of us sitting around idle the other months of the year? I don't think so. This is the busiest industry during the rest of the year that you can imagine.

Now, so much in general for the responsibilities of management. I am only trying to key up thinking. Let me say a word about our responsibility as individuals.

I have a thought about the typical sugar man which probably doesn't apply to anybody in this room. Let me tell you what a typical sugar man may be. Well, for one thing, he may be a man who tends to work much harder physically than he does mentally. None of you, of course, fall in that class! But I have seen such men.

A typical sugar man may be a man who is periodically over-optimistic or unduly pessimistic. That wouldn't apply to you! But I have seen him.

A typical sugar man may be a man who is skeptical of anything new. Not you! But I have seen him.

A typical sugar man may be a man who periodically convinces himself that the industry is on the verge of extinction. Not you! But you have heard about him.

And, finally, the typical sugar man may be the man who believes in rugged individualism regardless of the price paid for it. Not you, of course! But I know you have heard of such a man. Rugged individualism has been one of the great curses of this industry. This idea that we are going to have our own way regardless, and I mean competitively, has cost this industry a fortune again and again. Not only that, but it has held back its progress. Rugged individualism doesn't fit this kind of a world, in my opinion. What we need is men who sense the need for cooperation and who work together to accomplish results.

And so I would say to you who might possibly sense that some place in that list of the failings of the so-called typical sugar man there was one that fitted you (and I will admit to several of them), we need to be on our guard. One of the things that we must do individually is to avoid falling into routine thinking—just doing our work from day to day and not really thinking about it.

And let me point out to you one little practical suggestion about how to guard against routine thinking. It may not be of any value to you at all but the principle is still there. I maintain, just as a business keeps books,

or otherwise it wouldn't know where it was going, so the individual may very profitably think about keeping books on what he is doing. It isn't a bad idea to get some idea at the end of a day of what you have done. From that daily outline of what you have accomplished you can do something else that is really invaluable, and that is to keep a business diary of your own. The thing that amazes me is the fact that so many men work hard, but when asked point blank what they have done, they just can't remember. Well, that isn't serious; if somebody asked you what you ate three weeks ago, you can't remember. But it is a very important thing for you to know for your own guidance whether or not you have done anything worthwhile, for example, after a month has gone by. Well, if you keep a business diary then you can see for yourself whether or not you are really doing any worthwhile thinking and whether or not you are producing anything worthwhile.

It is a wonderful thing to work very hard, very earnestly, very sincerely, but if nobody knows anything about it, you are under a severe handicap. In other words, we need to learn the value of salesmanship in our efforts. We need to learn that if we do something, if we know something, if we discover something, somebody should know about it so that it can be put to greater use. All of us can profit by becoming salesmen of our ideas and efforts in an intelligent, sensible way.

It is our responsibility as individuals to increase our knowledge constantly. There are a great many men who know a lot but who overlook the fact that there is an absolute necessity for adding constantly to that store of knowledge. Your membership in this association is one of the means provided for increasing your knowledge.

Let me say a word along a little broader line. I think our industry is tremendously important in this country today. It is tremendously important to this country today for the basic reasons that I have been trying to develop here—the fact that it is made up of men who put work first. We are not an industry which is asking for more and more for less and less. We are an industry made up of men, as I said in the beginning, who *love* their work and who *work*, and there is a tremendous need for that in this country today. There is too much of a spirit developing in this country that somebody owes us a living; there is too much of a spirit developing that we should be getting more and more, as I said before, for less and less. You know, one of the grand things about this industry is the fact it is so rugged. You can't make a living in this industry easily, and that is perhaps one of its blessings. This industry is tremendously important to this country because we are keeping alive the pioneer spirit in a large group of people and we are also maintaining the dignity of man. Man is not dignified when he is led to think that he doesn't really have to work.

Well, I have digressed a bit because I want you to get the thought of what I mean by "Men of Faith." I don't mean it in any purely inspirational sense. I mean it from the standpoint that once in awhile it is a good thing for us to take a little look at our work and all its difficulties and struggles and then look back realizing that it has been a pretty good show from the standpoint of its basic accomplishments by individuals, by companies and by

the industry. When you put it all together, it represents what I like to feel and know is a great contribution to the welfare of this country at a rather difficult time.

Let me close by quoting again from that great book, "The Saga of Sugar":

> "Where there is no vision, the people perish. This is an obvious truth. Except for the imagination and faith of the leaders of the past, the world would still be an undeveloped wilderness. The progress of mankind has ever waited on the vision and courage of the few—the few who seem at times to abandon prudence in the interest of common good. The names of such go thundering down the ages while conservative men sink into nameless graves. And so it was with this great sugar saga—a few tipped the balances against the forces of nature, and the opinions of many. They unconsciously projected themselves into grateful remembrance.
>
> "Many present leaders of the industry still are young; they are aggressive; they have faith in those for whom they work. Most important of all, they believe with all their hearts in the future of the beet sugar industry. Owing to recent technological advances in seed and field mechanization and other phases, they look forward to a time when the industry, stabilized and competitive, will obtain a more eminent position in the national economy. Through this optimism, the faith of our fathers marches on."

I testify to you here now my absolute faith in the future of this industry because of its background; because it has awakened to the realization of the need for research; because it now has organizations like this functioning and because I have a hope that where you have men who really *work* and who *love* their work, somehow such an industry will receive protection thru all the difficulties that confront it.

Sugar Beet Problems in the Netherlands, As Contrasted With Those In America

HENK RIETBERG[2]

The beet sugar industry in the Netherlands is now about one hundred years old. The sugar beet was introduced into our Dutch agriculture in the first decade of the 19th century without much success, but after the erection of a sugar factory in 1854 in the southwest of our country, this crop found a growing interest and at the moment an acreage of 125,000 to 150,000 acres is normal for us, and our yield per acre is the highest in Europe.

The average yield per acre for the last ten years is 15.2 tons per acre, with a sugar content of 17.0%. In 1949 we had a bumper crop on 167,000 acres with an average yield of 18.2 tons per acre, but a sucrose content of 15.5%. Early in September the sugar content was normal, but then after rainfall new top growth suddenly started and the sugar content dropped considerably. This is probably an experience not unknown to American beet sugar factories.

With the expansion of sugar beet growing there was also an increasing number of sugar factories. Originally these were small factories with a very limited capacity, but gradually there came about a concentration of the industry and the number of factories was reduced. We now have twelve operating factories. The slicing capacity of the respective factories ranges from 2,000 tons to 5,000 tons, with a total for the twelve together of 34,000 tons in 24 hours.

An interesting feature in the development of our beet sugar industry is the fact that 60 percent of the sugar beet crop is processed in factories owned cooperatively by the farmers. As is well known, the cooperative idea is strongly developed among the Dutch farmers for many other purposes also.

As an average all over the country 5.0-6.5 percent of the arable land is planted to sugar beets, but in some districts the amount of land used in beet culture may be as high as 20 percent. Sugar beet growing is therefore not spread evenly all over the country but is mostly to be found in the west and northeast parts, mainly in those districts where the soil is clay or silt; only a limited acreage is found on sandy soils. The area per contract varies from 0.5 acre to an extreme of 1,000 acres, with an average area per contract around 4 acres.

As is probably known, a large part of our country is below sea level and so are most of the beet districts. Therefore, mostly the water level is sufficiently high for successful beet growing; irrigation, as is so common in many parts of the U.S.A., is not necessary.

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[1] Address delivered to the general meeting of the American Society of Sugar Beet Technologists, Detroit, Mich., Feb., 1950.

[2] Director, Instituut Voor Rationele Suiker Productie, Bergen Op-Zoom, The Netherlands.

The average annual rainfall is about 28 inches, and the average temperature in summer varies from 62° to 65° F. The rainfall is not evenly distributed, as February to June have less than 2 inches per month and July to November 2.5 to 3 inches, August and October being the rainy months of our climate.

In dry summers, however, there is sometimes not sufficient moisture for the beets. This may seem strange for districts below sea level, but for example, most of our islands in the southwest area (where 15-20% of the arable land is planted to beets!), are surrounded by salt or brackish water, and therefore it is impossible to fill the drains with water from outside the banks, even when water is badly needed.

The sugar beet seed used is all grown in Holland. The method used for seed growing is still from stecklings overwintered in clamps or pits because our climatic conditions make it impossible to overwinter the stecklings in the field, as you do in the United States. Therefore our beet seed growing is subject to more risks and the quality of the seed is less stabilized than in the U.S.A.

No breeding work is done by the sugar industry, as it is all left to private firms. There is, however, a very strict control on the varieties, as our Institute takes samples of all the seed delivered to the factories and this seed is planted on many variety trial fields spread all over the country. Only the sale of approved varieties registered on a special list is allowed in our country. This applies not only for sugar beets but for all other crops.

The general advice to the farmer is to plant at least two varieties, one early ripening for the early deliveries, and a late variety for the later part of the harvest. The basic idea is to get the highest economic production of sugar per acre, and as such a large part of the industry is owned by the farmers themselves. The factory results play an important part in the final decision on the varieties. Therefore, the varieties for early harvest have a higher sugar content but a somewhat lower root yield, whereas the later ripening ones are about 1-1.5 numerically less in sugar percentage but about 10-12% more in root yield.

The amount of seed used is about 15 pounds per acre of whole seed. The row width until a few years ago varied from 13-16 inchs. More recently, however, there has been a tendency to increase the row width to 20 inches on account of mechanization.

The number of plants aimed at as an ideal stand is 28,000 per acre. Some districts, however, are lower in number of plants per acre and the average over the country as a whole is 25,000 per acre.

What struck me among other things when I paid a visit to this country in 1946 was the wide range of variation in the use of fertilizers for beets, the amount used varying from none to fairly heavy dressings. A normal dressing for sugar bets in our country is 110 pounds of nitrogen per acre, together with 100-120 pounds of K_2O and 50-70 pounds of P_2O_5. In soils rich in potash and phosphate sometimes more nitrogen is given, but there is always the risk that too much top will be grown and a lower sugar content obtained. Also, in some cases the dressing of potash or phosphate is omitted, but mostly all three of these fertilizer elements are given.

Potash is chiefly given as 40% potash salts and phosphate as superphosphate. For nitrogen we prefer calcium nitrate or calcium ammonium nitrate. Ammonium sulphate is not very popular and mostly gives lower yields; Chilean saltpeter has been used to a large extent but its use entails the risk of crusting our clay soils when we have heavy rainstorms in spring.

As many of our beet growers have no cattle at all, manure is applied only to a limited part of our sugar beet soils. This brings the risk of a low percentage of organic matter, which on our clay soils leads easily to a poor soil structure. Our farmers try to overcome this difficulty by growing a green manure crop (especially red clover and alfalfa) in their rotations, but this seems to be not quite sufficient and the problem of applying sufficient organic matter is worrying many of our farmers and soil specialists. I understand from American publications that this is a problem we have in common.

On the sandy soils, cattle are being raised on all the farms and the farmers in these districts will not grow sugar beets without manure as they know by experience that on this type of soil good yields are only obtained when manure has been applied.

Mechanization of the sugar beet crop in the Netherlands is not to be compared to what is taking place in your country. There are a number of reasons for this difference. In a small country like ours with a very dense population it is necessary to get the highest yield from every square yard and very intensive farming is necessary. Our soil in the fall is very wet and sticky and harvesting the beet crop with heavy machinery ruins the soil structure, and thus has an unfavourable influence on the next crop. Also, the labor problem is less pressing than in the U.S.A., and the price of machinery in relation to wages of farm labor is much higher for our farmer than for the American farmer.

However, it must not be thought that there is no mechanization of our agriculture. On the contrary, much is done to mechanize our farming operations, but with machinery adapted to our special circumstances.

For sugar beets the use of segmented seed has been tried, but it proved to be too risky on many of our soils as it needs a very good seedbed or otherwise it gives a poor emergence. Since then we have tried various methods of polishing the seed and various types of precision planters more or less successfully. We have also found that the problem of soil structure is very important both in relation to mechanization of spring work and to mechanical harvest, and this brings us back to the problem of organic matter and bacterial life in the soil as especially important contributors to an effective and desirable soil structure.

The beet tops are very important to many of our farmers for the feeding of their cattle. As most of the tops are fed as silage it is a necessity to develop a harvesting method which enables us not only to save the tops but also to save clean tops. When the tops are soiled with clay, the risk of formation of butyric acid instead of lactic acid is great. Such silage is of poor quality and has a rancid odor. Cattle tend to refuse to eat improperly fermented silage.

Mechanization of harvesting operations is making very rapid progress, the usual system being first to top the beets mechanically and then to lift the topped beets with simple lifters or root harvesters.

Under normal harvest conditions the main problem is the dirt tare, as it is very difficult to clean the beets, especially when the soil structure is bad and the beets have developed many fangs, or, as you would say, forked or sprangled roots.

Soil structure has under our conditions many relations to beet growth and development. We have found that in the Netherlands at the end of June (*i. e.*, eight to ten week after drilling) we are able to judge whether the final root yield will be low, average or high. So the first growth and rapid emergence are very important. This is influenced largely by the quality of the seedbed and therefore by soil structure.

The influence of soil structure on the development of sprangled roots is very striking, and also we found that on soils of poor structure there are often more bolters, due to the fact that emergence in these soils is slower, and therefore the germinating seed is given a longer exposure to cold temperatures which induce bolting. It is therefore easily understood that part of our attention has been turned to the relations between soil structure and beet as an important factor for beet production. As these problems are very complex we work closely with soil specialists and hope that our sugar beet breeders will also pay more attention to these problems.

It may be interesting also to mention our beet transport. In a flat country like ours with many rivers and canals more than 60 percent of the beet transportation is by barges. Road or truck transport, under contract, takes about 15 percent, only 10 percent goes by rail, and the balance is by local deliveries. As a matter of fact, we have some factories having no rail transport at all. One óf these has a slicing capacity of 5,000 tons in 24 hours and will probably be enlarged to 6,000 tons, which shows the efficiency of barge transport.

Our climate being fairly cool in autumn, there is not much loss of sugar. Also we do not have the enormous quantities of beets stored at the factories as you have sometimes and the problem of ventilating the piles we do not know.

As in other countries we also have many pests and diseases in our crop. Of these I will only mention two as being of major importance: virus yellows and the beet eelworm or nematode.

The virus yellows disease has spread all over western Europe in the last twenty years and, if infection is early, losses can be as high as 25 percent. Up to the moment no means of combatting this disease have been found, neither do we have resistant or tolerant varieties as you have for the curly top virus.

Beet eelworm is a well known disease in many countries where beets are grown, but I will mention it here because, at the moment, it is one of our main problems. We have quite a few farms where no beets can be grown

at all because of the beet nematode. This very heavy infestation is due to the fact that farmers have grown sugar beets too intensively in their rotations. I was therefore very astonished when in 1946 I found that, in some of your western sugar beet districts, beet crops were grown in a very short rotation on farms where eelworm was present. As soil disinfection, at least under our conditions, is not effective we have developed a field control system. This is based on counting the number of eelworm cysts in soil samples and giving advice to the farmer when he will be allowed to grow beets again on a certain field. If we can find the time and the money we will try to make a complete map of the eelworm infestation all over the country.

In many districts sugar beets are grown not only for the roots but high value is put upon the byproducts. I mentioned earlier the use of beet-top silage. The same is true for pulp which is turned out partly as wet pulp and partly as dry pulp, both for use as feeds. In some districts on sandy soils the farmers more or less grow the beets for the tops and the pulp. They regard the sugar more or less as the byproduct!

Molasses is used partly for alcohol production, but another part is used for making silage. For example, young grass cuttings sprinkled with molasses give excellent silage.

The lime sludge is used for improving the pH of the soil. On some special types of soil it has a very beneficial influence. This is probably due to the fact that the calcium carbonate particles in the lime sludge are extremely fine and also the small amount of organic matter in the lime sludge has a favorable influence on the bacterial life in the soil.

The contribution of the sugar beet to the development of agriculture in many parts of Europe and particularly in the Netherlands has been a considerable one. At present the situation is such that in our country a well developed and well balanced agriculture cannot be thought of without the sugar beet crop, and we have no other plant which could take its place in the rotation.

Not only is the sugarbeet an important source of cash income for the farmer but through the value of the byproducts for cattle feeding his expenses for buying feeds are cut and more net profit is made. In some areas the tops only are estimated to have a cash value varying from $40 to $100 per acre. And to this can be added the value of the pulp and lime sludge.

From a general economic point of view the production of the larger part of the sugar consumed in this country by our own farmers is of basic importance. The introduction of the sugar beet in our agriculture has led to better farming practices and therefore has a favorable influence also on the production of other crops. Sugar beets therefore must keep their place in our crop rotation and we hope that research work done for this crop may lead to further improvement in the same way as has been done so successfully in America.

A Survey of Sugar Beet Mechanization

P. B. SMITH[1]

Historical—1900-1940

Most of the history of the sugar beet crop in this country dates back the last sixty years although there were factories in operation for several decades previously. A great deal has transpired since 1900 in methods of production of sugar beets. In the early years of the century the cost of thinning was only $3.00 per acre, and naturally there wasn't much incentive for mechanized thinning, although we find in the records that many machines had been patented prior to that time for sugar beet harvesting. Commonly beet growers planted 20 to 25 pounds of whole seed per acre in drills which were not too satisfactory except to distribute the seed in the row. The early cultivating equipment, even that used 25 years ago, was mostly cast iron and horse drawn. The tools were not accurate and were generally made by local blacksmiths—in fact, we did not have tractors in beet fields much before 1930 and at that time they were used principally for plowing.

The first field loaders were used about 1939 and beet harvesters on a successful basis came along about the time the war started. Processed beet seed started at about the same time. Researchers experimented considerably with fungicidal treatment of seed before the war but it was not commonly used to protect the young seedling against seedling diseases. We did very little about weed control except to leave it to hand labor. Mechanical thinning was done as early as 1919 by Hans Mendolsohn and others by using th common harrow, but it was not successfully applied commercially. The first mechanically thinned beets which were carried through to harvest were, to my knowledge, in an experiment about 15 years ago in Colorado, where the Uddenborg blocker was used quite successfully on whole seed planting, with a reduction in yield of only about one ton even though no hand thinning was done in the experiment. The difficulty at this time was in getting hand labor to top multiple beets. All of these things lead up to our present state of development which we might consider as the period just following the start of World War II.

Rapid Mechanical Development—1941 to 1950

It is interesting to make a comparison on the man hours of labor required to produce an acre of beets. Fortunately we have some very good figures on surveys which have been conducted:

Table 1.—Reduction in Labor in Beet Production.

	1924	1949	1955?
Man hours required per acre to produce sugar beets	115	68	40
Average beet yield (Tons)	9.2	14.0	15.0
Man hours required per ton	12.5	4.8	2.7

[1] Secretary-Manager Beet Sugar Development Foundation.

You will note that, probably to the surprise of many people in the agricultural departments of beet sugar companies, we have made a very material reduction in the man hours required per acre. If this did not include considerable hand labor, the figure for 1949 would be lower. Most of the gains between 1924 and 1949 have been occasioned by the use of tractor methods. The beet yield average for the United States 25 years ago was 9.2 tons on 925,000 acres. There has been a gain in 25 years, through the use of better adapted seed and more timely methods, of nearly five tons to the acre. When this production is translated into man hours per ton of beets you will note that the figures today show that we use only about 40% as much labor in beet fields as we did in 1924. We still are going to make more rapid progress and I have compiled some tentative figures for five years hence as a goal, which may prove to be too conservative.

Only in the last five years have we made rapid machine development in the harvest. In 1945 we harvested about 7% of the acreage of the United Stats mechanically. In 1949 this reached almost 52% which is very well explained in the listing of the United States beet growing areas in Table 2, divided according to areas in which production methods are similar:

Table 2.—Proportion of Sugar Beet Production by Machine Methods

Area	States Included	Harvest		Spring	
		1946	1949	1946	1949
1	California	58.8	72.6	2.57	1.33
2	Washington Oregon Idaho Utah Arizona Neyada Western Montana Western Colorado	4.19	63.1	2.78	19.78
3	Montana Wyoming Nebraska Colorado New Mexico Western North Dakota Western South Dakota Kansas Texas	10.14	48.69	2.07	32.03
4	Eastern North Dakota Minnesota Iowa	.97	38.9	61.74	58.3
5	Wisconsin Illinois Indiana Michigan Ohio	4.42	35.58	.....	.....
	U. S. Machine Methods:		1946	1949	
	Harvest		16.83%	51.89%	
	Spring[1]		7.71%	29.84%	

[1] Area 5 not included.

It must be understood that we are now employing almost entirely processed seed, that is, decorticated, segmented or otherwise processed to break down the whole seed, and also are employing mechanical and chemical weedings and other methods to assist in reduction of labor, so you can see readily the progress which has been made in a very short period. More than 100,000 acres in the western part of the United States in 1949 had some form of spring mechanization. This is reaching important proportions in some areas and we can understand readily the reduction in labor caused by these practices.

A study made in 1949 shows a saving of 42.72% in the hours of labor in those beets mechanically harvested. It shows a saving of 35% in man hours of labor for mechanical thinning tools used which represents, in our opinion, a very excellent progress to date, even though we must recognize that mechanical harvesting is still not too efficiently done, the by-products are not too well conserved and the beets are not of as high a quality as we would like to have for processing due to trash and improper topping. However, we now put beets into the storage pile with mechanical harvesters which are much lower in temperature than the hand-harvested beets and hence they keep much better in storage.

The mechanical thinning practice on 1949's 100,000 acres is far from perfect, but the development of machines and techniques required is coming along very nicely even though it is in the "Model T" stage. Spring mechanization naturally will reach greater perfection as soon as farmers have had opportunity to experiment and gain confidence. This has proven true with mechanical harvesters and already in the four or five years of our mechanical harvesting experience we have gained considerably in the modification and improvement on harvester machines. You might be interested in some comparisons compiled from many experiments and studies on the subject of time studies in spring mechanization. This is shown in Table 3 in which hand blocking and thinning whole seed is used as a check or standard.

Table 3.—Labor Requirements for Different Spring Procedures.

Hand blocking and thinning whole seed (timely)	100.00%
Hand blocking and thinning processed seed	80.00%
Long Handle hoe thinning	70.00%
Thinning after mechanical blocking	60.00%
Weeding after mechanical thinning	50.00%

You will note what processed seed has given us in the way of saving and, in many cases, this has been greater than that shown in these "rounded figures." With improvements in general farming methods the mechanical blocking and hand work can be entirely eliminated, in our opinion, in a few years time if strict attention is paid to a program for complete mechanization.

I remember a test conducted in 1949 at Colorado A & M College comparing a number of mechanically handled plots with whole seed. The whole seed was planted at the rate of 24 pounds per acre and the processed seed at 10 seeds per foot. It is interesting to compare the saving in time between

the best mechanically handled plots and the whole seed when thinned at a timely size. In fact, only 18% of the labor was required on the best mechanically handled plots as compared with the check. The yield was practically identical although there was a reduction of more than six tons per acre when the thinning time of the whole seed plots was delayed 10 days. This is a point which many of us overlook—even the last five years has made a difference in our memories in this respect. Processed seed has a much better possibility for good tonnage even though it might be thinned slightly on the large size. We have made large acreage gains in the use of processed seed commercially to eliminate this decrease in tonnage. With the use of mechanical methods a further competition is reduced to a minimum and when the work is done at the proper time it would appear reasonable that increases in yields will result.

A Program for Mechanization—1950-1955

Any survey of mechanization in the United States would not be complete without setting down a definite program for development of improved machine use in the next few years. I have chosen to list in some 11 or 12 different items, for the sake of brevity, some of the important features of such a program:

1. Rotation. Rotation, or crop sequence, is very important to fulfillment of our aims in complete mechanization. This comes about through weed control in the preceding crop, not the crop of beets.

2. Weed Control Chemicals in Grain, Corn and Other Crops Ahead of Beets. The use of 2,4-D and Dinitros and other forms of weed chemicals to kill weeds in growing crops has become quite a popular practice and should be taken advantage of in our cropping system. Strict attention should also be given to fence rows, ditches and waste areas which might mature seeds and infest cultivated fields. We have all seen evidences of such good farming practices and how well they reflect in better yields and lower cost of producing the crop. Prepare seed beds early in areas where weeds germinate before normal beet planting. Use pre-emergence sprays at planting time in these locations.

3. Weed Control Districts. In a great many states laws provide for the setting up of weed control areas by townships or counties, where the county and state set about to take care of not only obnoxious weeds but also weeds along highways, drainage ditches and other public properties which might infest farmers' fields. These can also be extended in some states to weed removal on privately owned farms where the farmer has not handled his farm cleanly.

4. Fall Plowing and Fallowing. We all know the advantages of fall plowing in improving soil structure, water holding capacity and improvement, of course, in germination of seed as well as weed control. The practice of summer fallowing after spring plowing of such crops as sweet clover or alfalfa is a growing one because it not only improves the tilth but controls the weeds very effectively. These methods, of course, cannot be followed on light or blowy soils.

5. Seed Bed Preparation. We should not omit in our mechanical suggestions the proper preparation of seed beds. A light harrowing just ahead

of planting might well eliminate a weed problem. More thorough packing of the soil might improve the chances of getting a good stand in some soils. The use of ridge cover planting might be called an item under seed bed preparation in that we are preparing the soil for the seed in order to raise the moisture and hold it around the seed and, when the ridge is removed, weeds are eliminated. This has been practiced very successfully on thousands of acres.

6. Seed. Processed seed, we feel, should be used solely and that is more or less what has happened in the last few years. Ten to twelve seeds per foot, and not less, should be planted, except on very good soil conditions where chances of getting weeds are small. The relation of the size of the seed to cell size of the plate is very important in order to get an improvement in drill efficiency and distribution of seed. The seed should be treated with fungicide and also with other chemicals where certain types of insect damage can be prevented.

7. Use Precision Drills. There are several drills which we would class as precision even though they might yet have some weaknesses which will be overcome in future development. Flute feed, internal feed drills and others of this type should not be used as their bunchy characteristic does not lead to a seed pattern which gives us a minimum of multiple plant hills. Speed of drills is important and we have found that it has a relation to the depth of the seed as well as to the distribution of the seed. Planting too rapidly makes for an erratic seed pattern and also some of the seed bouncing in the furrow to the extent that it is not covered as deeply. Use new, unworn seed plates in order to get maximum cell fill and good seed pattern. Use plates which are fitted to the size of seed to avoid erratic results. The new type drilling devices which compact the soil under the seed and leave a mulch of soil over the seed have shown a great improvement in emergence and lessening of crust danger. We feel that this type of planting is going to grow in favor because of its generally great improvement in emergence over the old type shoe runner disc opener with concave press wheel type of drill. Experiments are going on further on a larger basis to prove the adaptation of the furrow former wheel to be used in place of present furrow openers.

8. Mechanical Blocking and Mechanical Thinning. This at the present stage of development is advisable inasmuch as our agronomic practices are not yet at the point where we can safely plant the seed where we want the plants to remain, and for that reason we recommend either mechanical blocking or mechanical thinning. This may be done down-the-row or across-the-row, as the farmer chooses. There is an advantage in the small rotary knives now developed as a modification of some of the down-the-row equipment in that it is possible to leave, say, three small blocks an inch in size instead of one block three inches in size. This permits more rapid long handled hoe trimming by beet labor and if a machine is used two or three times in stands which are sufficient, the hand labor might be completely eliminated because of the increased number of singles following such a

procedure. There is very good evidence that this system will grow in popularity. It is well to note that it was tried 15 or 20 years ago with very good success as a down-the-row blocker but not, of course, adapted to across-the-row blocking on all soils inasmuch as it is not possible to make the narrow blocks which you get with the rotating knives. There are some new tools which have been developed for down-the-row blocking that are simple and give very good chances for commercial success.

There are probably three things which have caused a failure on mechanical blocking and thinning—these must be avoided if successful spring mechanization is going to take place: (1) Farmers waiting to block beets as a last resort. I have been called out a number of times by farmers who expressed a desire for mechanizing the spring work to look over their fields and, to my surprise and disgust, find beets a foot in height with weeds even taller. Too often farmers have little conception as to the proper time to employ machines. In spite of this, we have word from many individual growers who used machine blocking in 1949 to save their crops. They were satisfied with the result apparently, but how much better it would have been if they had planned their spring mechanization in advance. (2) Using machine blocking when stands are insufficient. We have had a rather embarrassing start in some places by attempting to use mechanical blocking when we had only 10 or 15 plants per 100 inches of row. In order to achieve equal tonnages with hand blocking and thinning it is necessary to have at least 25 plants per 100 inches, and we should think in terms of possibly 40 plants per 100 inches in order to achieve equal success with the yields from hand blocking. This goes back to a repetition on the recommendation of heavier seeding rates. (3) Letting weeds get ahead of beets. This quite often happens through no neglect of the farmer but through rainy weather or extremely dry conditions when the beets have not come up and weeds have gotten ahead. In some of these cases, we would advise, if not too late, the reworking of the ground and replanting of the beets. This should not be allowed to happen and will not take place if good weed control, crop sequence, fall plowing and fall irrigation are possible. Weeds, in the small stage of growth, can then be eliminated by using spring-tined weeders.

9. Mechanical and Chemical Weed Control. At the present time we do not have any selective weed chemical control which we could advise farmers to use generally. Some farmers could quite successfully use salt sprays employing saturated solutions (say 200 pounds per acre), but in many other soil areas this cannot be recommended. The experimental use of 160 pounds of polybor looked optimistic in the University of Manitoba weed experiment last year and may have some promise for commercial adaptation as a selective weed killer.

Spring-tined weeders are our best means, at the present time, of eliminating weeds. These can include both the rotary weeders which go down the row as well as the stationary tined weeders, such as the finger or pencil weeder, which can go at an angle to the row. There are many quite successfully used weeders of this type which are highly effective when the weeds are small. We find some danger of using them in dry weather con-

ditions and in conditions when the beets are too small, where the tines may cause a covering of the beets in the initial stage. We would suggest, for safety sake, that they not be used until the beets have at least two true leaves and better at the four leaf stage. A new adaptation of the spring-tined weeder on the rotary principle was used at Fort Collins last year which has a half inch knife on the tip end of the fingers. This worked out very satisfactorily for removing weeds and was quite useful even in beets of the cotyledonous stage.

10. Cultivation. More attention needs to be paid to proper cultivating. Farmers can no longer consider that they have fulfilled their job when they leave a 10-inch space, five inches on each side of the row, to be cleaned out by hand labor. They are going to have to think of a very narrow cut and also the use of knives placed in reverse from the present procedure which will tend to push some soil over against the plant. The use of knife-edged bull tongues in early cultivations as well as deer tongues and shovels for later cultivations where the soil is moved over slightly against the plant to cover the small weeds growing immediately in the row seems to give good control. The "Culti-Cover" tools act like a road grader, scrape away from the row with the first blade and push moist soil up against the beets with a second blade for covering weeds. There are also some rotary discs which are being tried for a similar type of work. These ideas can very successfully be used to eliminate hand weeding after thinning and cultivations should go along as long as possible during the season. For that reason we suggest that in many areas the row widths be widened to at least 22 inches, sacrificing perhaps some yield and sugar content for the benefit of lowering costs of production. These things will come in spite of us and we might just as well work to that end now, realizing the full benefit of mechanical practices in eliminating hand weedings.

11. Mechanical Harvesting. Mechanical harvesters are now being used on more than half of the beet acreage of the United States, and in many areas this approaches 85% and 90% of the acreage. We will continue to see improvement, particularly along the line of the development of harvesters, for four purposes: (1) To better handle the feed value of the tops and to deliver to the receiving station beets which are free from stringers and trash; (2) The development of a small harvester adapted for growers with less than 20 acres, which at little overhead expense can properly harvest small contracts; (3) The development of three- and four-row self-propelled harvesters which can handle large acreages daily, for use of large growers and custom type operators. This type of machine naturally has been very popular in grain harvests and we can look forward to development of this principle for sugar beets; (4) Improvement of present machines to eliminate totally need for hand sorting, and to enable reduction of power requirements.

Complete Independence of Field Labor

In the not too far distant future, we foresee, with the hundreds of research workers devoting time to the development of methods and machines and chemicals, that we will entirely eliminate hand beet labor from the production of sugar beets.

This will mean that we will have a beet drill which can plant in a precision-like way so that the seed, which may be 100% single, or possibly double germ in character, will produce a plant at the interval required under those conditions or giving the stand which normally can be developed. The chemical selective weeds sprays can then be applied after emergence of the plant and at successive intervals later in order to control weed growth before it develops. Spraying equipment which sprays directly on the soil underneath the foliage can well be developed for this use.

Beet harvesters which require no hand sorting of clods or handling of levers are in the offing with which hand labor will be a minimum. This will mean that contracts up to the size of 40 acres can be handled entirely by the farmer and his hired man.

We see evidences pointing to this ultimate production goal at the present time. In 1949, for example, in California a very good experiment was put on by a large grower comparing a precision planting with ordinary planting. The yield was in favor of the beet seed which had been precision-planted every three inches as against a rate of six pounds per acre for the non-precision planter. The yield was better than a ton per acre to the advantage of the beets which had received no thinning. Because of the weed control practice on this farm, the weed problem was not great and no extra charge was made by the labor for the weedings.

This type of thing can be looked forward to on a large scale in the future. We have developed methods in other areas, such as the Red River valley, where only one weeding has been necessary, even with our present knowledge and methods. The addition of chemical weed control to crops preceding beets, better rotation and selective weed killers, can readily give us the prediction that the beet crop of only a few years ahead will be raised entirely without the use of hand labor.

The future farm situation generally is one of ability on the part of farmers to oversupply the market. It is very important in sugar beet producing areas that farmers are acquainted with a half dozen things which they can do:

1. **Raise crops mechanically and as cheaply as possible.**
2. **Increase acreage of crops which are not in as great a prospective surplus.**
3. **Produce as high yields as possible on every acre.**
4. **Grow crops which fit into a livestock program.**
5. **Practice soil improvement through good rotations and use commercial fertilizers for maximum fertility.**
6. **Keep informed about general political and business conditions.**

Production of By-Products of the Sugar Beet Industry

PAUL D. V. MANNING[1] and M. J. BLISH[2]

Technical men outside of the sugar industry are apt to view the manufacture of sucrose from sugar beets as a most interesting and somewhat complex process. Those of us who are not sugar technologists are frequently astonished at the amount of knowledge that has been developed in that industry, at the smoothness of its operation, at the degree of operational standardizing which has taken place between competitors, and, finally, at the uniformity and purity of the product.

Presumably it is because those in the sugar industry have spcialized in producing the highest grade product at the lowest possible cost that such a degree of perfection has been attained. At any rate, the development of an extensive enterprise based on the treatment of the wastes of the sugar industry has in part been carried out by others. These waste products are the raw materials for a number of different manufacturing operations.

As an example, beet molasses is the raw material needed for the production of yeast and much of the citric acid produced in the United States. Sugar beet pulp has become a very useful part of the animal feed industry and even the beet tops now seem to be useful in the manufacture of a certain specialized animal food.

In the case of molasses the technical progress of the sugar technologists caught up with yeast and citric acid manufacturers through the steffenizing of molasses so that now there is competition for molasses by the producers of yeast and citric acid on the one hand and the Steffens plants on the other. We are advised that beet molasses is actually now being imported from Holland by the fermentation industries.

It remained, however, for one of the sugar producers, James E. Larrowe, to initiate the commercial production of by-products from Steffens waste. During the first World War, a number of the beet sugar plants, including a factory owned by Mr. Larrowe, produced a crude potash salt by concentrating Steffens waste and burning the concentrate. After the war, when potash production from this source was no longer profitable, it was noticed that even at temperatures of 30° below Fahrenheit zero the Steffens concentrate was still quite fluid. Detroit, even then, was the center of the motor car industry and Mr. Larrowe, as a fellow resident, knew many of the leaders in this field.

Drivers of automobiles were using their cars during the winter and a good, low freezing coolant competitive to alcohol and glycerine was greatly desired. At the request of an interested party, Mr. Larrowe had some of the

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concentrate packed in cans. This was sold for antifreeze. It turned out to be an excellent product from the standpoint of protection of the cooling system from freezing. However, it had a most questionable value in the field of repeat orders because within a short time the user found it necessary to order a new radiator and soon thereafter a new engine block. While it prevented freezing, it also corroded metal parts when it was diluted and heated. The story of this phase of development as told by Mr. Larrowe gave us many a pleasant moment.

Threatened with abatement proceedings against his sugar factories because the Steffens waste polluted the rivers, and still thinking that future use for this material might lie in the antifreeze field, Mr. Larrowe arranged for work to be carried out at the Mellon Institute on this problem. The material's glutamic acid content indicated that it might be a source of raw material for the production of monosodium glutamate and preliminary designs were made for a plant. Publication of this in a technical journal resulted eventually in a combination of the Larrowe interests with those of the Japanese firm of S. Suzuki and Company for the purpose of manufacturing monosodium glutamate, then being sold under the trade name of Aji-no-moto.

Glutamic acid is a very interesting and peculiar chemical substance. It exists in three different chemical forms. These are the L and D isomers and the racemic mixture. The monosodium salt of the L or naturally occurring form has the property of bringing out flavors of substances to which it is added. Not all of these flavors are pleasant—it can and does intensify some of the poor ones as well as the good.

Originally it was made commercially from sea weed and then from wheat gluten. In the case of gluten it is liberated from the protein by hydrolysis effected by a mineral acid. Made from this raw material, it is quite difficult to purify. The non-amino acid products of the action of a mineral acid on a gluten containing some starch are extremely flavorsome and were not all removed by the methods then used for production of monosodium glutamate. Consequently, monosodium glutamate was credited with having a meat-like flavor, which when pure it does not possess.

Troubles beset the Larrowe-Susuki enterprise, mainly because of the corrosive nature of the reagents used in the process and the lack of knowledge as to the chemistry of the constituents of the Steffens waste water. As to the latter, we now know that the technical department of at least one large beet sugar company had developed through years of research a considerable amount of fundamental chemical knowledge on the constitutents of Steffens waste.

Commercial production of high purity monosodium glutamate from any raw material, although it may appear simple, is successfully carried out only by means of a complex and exacting process. Originally the precursor of glutamic acid in the sugar beet was thought to be a protein. Now it is pretty definitely known that it is glutamine and that this constitutes a means of storing nitrogen for later use by the beet in its metabolic process. Had research developed that fact at an earlier date, a large amount of money might have been saved.

Most of the glutamine in the sugar beet passes as such into the diffusion juice, and there it begins to decompose, forming ammonia and the internal anhydride of glutamic acid, pyrrolidone carboxylic acid. This reaction may go nearly to completion during lime defecation. Since pyrrolidone carboxylic acid is hydrolyzed to glutamic acid quite easily, and since this change is reversible, an equilibrium between the two can be established in any aqueous system, depending upon the conditions of temperature, pH and possibly the concentration of certain other constituents. Consequently, both glutamic acid and pyrrolidone carboxylic acid are usually present in Steffens wastes. However, because of the equilibrium conditions, there is a much higher proportion of the anhydride than glutamic acid.

In much of the earlier work described in the literature on Steffens waste, it apparently was not recognized that the waste as discharged from the filters was very unstable and subject to bacterial decomposition. Certainly it was not generally known at that time that most bacteria can and do use glutamic acid in their growth. Consequently, the results of some of the earlier work must be viewed with doubt because of the possibility of bacterial decomposition.

Since the precursor of glutamic acid in the Steffens solution is in reality its anhydride, pyrrolidone carboxylic acid, the change to glutamic acid is an hydrolysis in the true sense of the word. One molecule of water is added by the reaction. This accounts for the fact that the hydrolysis can be saitsfactorily carried out by either acid or alkali as the hydrolyzing agent. On the other hand, in the hydrolysis of proteins such as the cereal glutens, the use of an alkali as the hydrolytic agent invariably results in the production of the racemic form of the amino acids.

As pointed out above, glutamic acid exists in three chemical forms. The same is true of the monosodium salt. Only the L form, or natural isomer, is active as far as the property of flavor enhancement is concerned. There is no simple low cost method known by which the racemic mixture can be resolved and the L form separated from the D.

As previously stated, however, the hydrolytic change of pyrrolidone carboxylic acid to glutamic acid may be effected without racemization through the use of an alkali as well as an acid. The process originally developed by the Mellon Institute and used by Mr. Larrowe made use of hydrochloric acid as the hydrolyzing agent. Knowing with what great difficulty we handle this acid even today, we can well sympathize with the management of the plant who watched the equipment literally dissolve in the solution within a relatively few months. Professor Ikeda of the Suzuki technical staff developed a process using sulfuric acid instead of hydrochloric, but this presented difficulties which even today have not yet been entirely solved.

Throughout all of this early development period, there is no record of anyone having courage enough to doubt the then accepted idea that glutamic acid was present in the Steffens waste as a part of a protein. About the time the plant dissolved in the solutions being processed, Dr. Albert E. Marshall was employed as a consultant by Mr. Larrowe, and it was he who decided to attempt the hydrolysis with caustic soda. This is the basis of the

process now used by International Minerals and Chemical corporation in its plants at Rossford, Ohio, and San Jose, California.

The use of alkali, although much more satisfactory than acid from the standpoints of equipment and process, is not altogether free from difficulties because racemization of the L glutamic acid can be caused by treatment with alkali under certain conditions. However, this can be prevented and a nearly perfect hydrolysis attained through exact control of temperature, time, pH, and ratio of total alkali to the concentrated Steffens filtrate used.

Amino acids are complex and peculiar chemicals. Much too little is known of their chemical properties and particularly of their solubility relationships in aqueous solutions as influenced by the presence of other substances, both organic and inorganic. The sugar beet itself is a storehouse of miscellaneous organic compounds. After these have passed through the treatment given the diffusion juice in the production of sugar, including the Steffenizing and recycling operations, this raw material for the production of glutamic acid becomes a fearful and wonderful collection of variables. Many of the substances in the Steffens waste change and decompose into other interfering products during processing with alkalis, acids and heat.

In any chemical process the first care of the management is to do as much as possible to see that the raw materials are uniform. This has been the endeavor of beet sugar technologists working with the beet growers. Reduction of so-called "harmful nitrogen" and increase in purity of the beet have been and are a constant means towards this end.

Some problems which we encounter in the manufacture of monosodium glutamate are related directly to the methods used by the manufacturer of beet sugar to overcome his difficulties. Others are due to the unique characteristics of the glutamic acid itself.

First, an attempt to reduce the "harmful nitrogen" in the sugar beets may result in a reduction of the already small percentage of glutamine in the beet and consequently the glutamic acid in the Steffens liquor resulting from the processing of these beets. Dr. Hac and her co-workers at our Woodland, California, laboratory have shown that increasing the application of plant food nitrogen to the soil results in a large increase in the glutamine content of the beet, while the reduction in purity may be compensated for by a considerable increase in tons of sugar per acre.

Increased use of nitrogen fertilizers to build up a higher glutamic acid content in the beet itself does increase what is termed "harmful nitrogen." This has long been objectionable to sugar technologists. The sugar producer wants his sugar factory liquors as free from "harmful nitrogen" as possible. Conversely, the glutamic acid producer wants his starting material as *high* in glutamic acid as possible. Although these ideas have usually been considered incompatible, we now find different schools of thought on this subject, and there is some hope for the belief that the problem can eventually be solved to the mutual benefit of both parties.

Very laudably there is a free interchange of technical information among sugar technologists. This gave some reason for our perhaps rather naive

assumption that, within reasonable limits, the sugar content of the concentrated Steffens wastes produced by most factories would be as low as possible and fairly uniform. We installed large multiple effect evaporators in a number of Steffens plants and contracted to purchase the concentrated waste for a long period of years. Great was our surprise when analysis of the Steffens concentrate showed the sugar content to vary from about 5 per cent to as high as 18 per cent, based on 65 per cent solids in the concentrate. One producer sold us Steffens concentrate containing several thousand tons of sugar in one season. The sugar is a distinct detriment to us since it greatly lowers the extraction of glutamic acid by decreasing the concentration of glutamic acid in the concentrate and increasing the end liquor losses. It has sometimes seemed to us that the Steffens house is an orphan child at many sugar factories, for certainly many hundreds of thousands of tons of sugar have been wasted because this part of the sugar process is not always as well operated as the rest of the plant. There is some evidence that sugars in Steffens concentrate many result in the formation of substances which interfere with the extraction of the glutamic acid values. Research is in progress on this at the present time. Those of us who are concerned with returning values to you for the Steffen waste produced in sugar operations do respectfully invite your attention to the possibility of recovering more sugar from molasses by better operation in the Steffens house.

It is evident from the foregoing that the production of glutamic acid from Steffens waste water really begins with the molasses as it enters the desugaring process. In the future it may begin with the beet grower, but the research upon which this idea is based is not yet entirely complete.

In the production of monosodium glutamate, the thin Steffens liquor is carbonated as soon as produced and the calcium carbonate thereby precipitated is removed by thickening and filtration. It is then concentrated to about 65 percent solids in evaporators usually having five to six effects with one high concentrator. This concentration ratio is between twenty and twenty-five to one. The concentrate is run into storage tanks and shipped at intervals to our San Jose factory where it is blended with concentrate from other points and stored in seven large tanks, each of 1,500,000 gallons capacity. During storage some salts crystallize out. The term "waste," when applied to anything connected with beet sugar operations, is frequently associated with the foul smell which emanates from the cattle feeding lots using undried beet pulp. We have therefore chosen to call our raw material "Concentrated Steffens Filtrate" or "C.S.F."

Passing now into the process, the C.S.F. is first weighed and then filtered by an Oliver precoated filter to remove suspended solids. If concentration has not been carried far enough at the sugar plant, it is reconcentrated at this point but this is a step not usually needed. The filtered C.S.F. is then run into steel hydrolyzers where it is carefully mixed with a 50 percent solution of caustic soda. Careful control of the total alkali, temperature and time are required at this point to make sure the conversion of the pyrrolidone carboxylic acid is as complete as possible and that there is no racemization of the L glutamic acid.

Following hydrolysis, the liquid is cooled by a heat exchanger and partially acidified with hydrochloric acid. Automatic pH control insures proper processing in this step. The solution is then concentrated in a single effect flash-type evaporator. In this evaporator all parts in contact with the liquid and vapor up to the jet condenser are rubber lined with the exception of the heater and forced circulation pump. The outside heater and pump are made of type 316 stainless steel. The concentration results in the crystallization of mixed sodium and potassium chlorides containing about 30 percent K_2O. This is removed by means of Bird centrifugals.

After removal of the inorganic salts, the filtrate is further acidified, the pH being adjusted to 3.2, the isoelectric point of glutamic acid. The acidified solution is then cooled and run into large rubber-lined crystallizers. The crystallizing of the glutamic acid is a slow process requiring from five to eight days. When this step is finished, the crystals are separated by centrifugals operating at a speed somewhat higher than that usually used in the centrifuging of sugar. The filtrate is the end liquor from the process and is either processed for production of betaine or is discarded.

The crude glutamic acid is then purified, dissolved in a solution of caustic soda, decolorized, concentrated and finally crystallized in La Feuille crystallizers. The monosodium glutamate crystals are separated by centrifuging, dried, screened, and packed. The mother liquor is reboiled several times for additional crystals, the final mother liquor being returned to the process.

The purity of the product exceeds 99 per cent. Impurities consist mostly of exceedingly small quantities of sodium chloride and aspartic acid.

Corrosion is an exceptionally difficult problem throughout the process after the hydrolysis step. A mixture of mineral acid, especially hydrochloric, with glutamic acid will act on all but a few metals.

Any possibility of noxious fumes from the plant is avoided by venting all tanks and reaction vessels into a fume collecting and treating system. The fumes are passed through an alkaline scrubbing system and then vented to the boiler stack.

Although glutamic acid is currently the most valuable substance recoverable from Steffens filtrate, there are also other constituents which deserve consideration. The most conspicuous among these is betaine, a methylated derivative of glycine. Betaine has long been known to occur in beet juices in greater abundance, on the average, than any individual component of the so-called "harmful nitrogen" group, although in exceptional cases it ranks second to glutamic acid. Betaine is highly soluble, relatively inactive chemically, and practically none of it is removed in the normal sugar purification processes but is carried through the sugar factory into the molasses and into the Steffens filtrate.

Among beets from different sources, the betaine content appears to be much more uniform and constant than is the case with glutamic acid. Molasses usually contains approximately 4 to 5%, while 8 to 10% is normally found in concentrated Steffens filtrate.

The isolation and recovery of betaine from crude raw materials is based upon the fact that its hydrochloride has a low solubility in strong hydrochloric acid. When aqueous solutions containing betaine in appropriate concentration are strongly acidified with hydrochloric acid, betaine hydrochloride is deposited in crystalline form. The yield and purity depend upon the original concentration of betaine and upon the nature and quantity of associated substances present in the starting solution. Concentrated Steffens filtrate can be used satisfactorily as a raw material for the isolation and recovery of betaine hydrochloride by this method. Other source materials from which betaine is similarly recoverable are the concentrated residues from the alcoholic fermentation of beet molasses and the waste liquor resulting from the processing of concentrated Steffens filtrate for the recovery of glutamic acid.

Several expired patents, including those of Tressler (1), Ikeda (2), and Takayama (3) have disclosed various modifications of procedure based upon recovery of betaine, as the hydrochloride, from these types of raw materials. A relatively recent patent of Bennett (4) teaches the processing of thin Steffens waste water by means of ion exchange resins to recover the nitrogenous constituents in concentrated form, thereby providing an appropriate starting material for betaine production. It also discloses an alcohol extraction process applied to concentrated Steffens filtrate, followed by an ion exchange purification of the extracted betaine.

When betaine hydrochloride is precipitated from beet waste liquors with strong hydrochloric acid, it is usually contaminated with sodium and potassium chlorides. The precipitate may also contain glutamic acid hydrochloride if a substantial amount of this amino acid was present in the starting material. One method of purifying the betaine hydrochloride is to extract it with hot alcohol, from which it may be crystallized on cooling. Another consists of dissolving the crude product in hot water, decolorizing with carbon, concentrating and recrystallizing the hot solution.

Betaine, itself, as the monohydrate, can be prepared from the hydrochloride by any of several different methods. One consists of extraction with hot alcohol, after neutralization of the hydrochloride. Another involves heating with sulfuric acid to drive off the chloride, followed by precipitation of the sulfate with calcium or barium. Also, the hydrochloric acid may be removed by passing a solution of betaine hydrochloride through an anion exchange resin. In view of the extraordinary hydroscopicity of the betaine monohydrate, it is preferably stored and dispensed in the form of its hydrochloride, rather than as the monohydrate.

Potentially the quantity of betaine recoverable from waste beet liquors is obviously very great. So far, however, the market demand is relatively small. Betaine can be used successfully as a starting material for the preparation of dimethylamine and trimethylamine, and for methyl-chloride, but apparently it does not compete successfully with other and more economical materials available for such purposes.

Several patents have been issued covering the use of betaine acid chloride as a starting point for derivatives, of which some are claimed to have useful properties as surface active agents, fungicides, insecticides, corrosion in-

hibitors, textile improvers, and as solubilizers for various dyes and pharmacologically active compounds. There is no evidence known to us that these derivatives are actually used commercially to an extent involving large tonnages. It is possible, of course, that they are utilized industrially to a much greater degree than is generally realized, but that the betaine is made synthetically instead of being recovered from natural sources.

Medicinal preparations of betaine hydrochloride under the name of "Acidol" have for many years been used for administration to persons troubled with insufficient gastric acidity, and various other minor pharmaceutical uses have been noted.

Betaine is apparently non-toxic, and although formerly regarded as physiologically "inert" more recent findings indicate that it functions usefully as a methylating agent in metabolic processes. The presence of labile methyl groups for transmethylation purposes is now regarded as of nutritional importance equal to that of vitamins and other essential dietary constituents which cannot ordinarily be synthesized in the body but must be supplied in food. Reactions involving transmethylation are particularly essential to the proper functioning of the liver and kidney. Although methionine and choline were at first considered to be the exclusive transmethylating agents it has since been reliably established that betaine can also serve effectively as a methyl donor, and that it can act as a capable substitute for either methionine or choline insofar as the function of transmethylation is concerned.

Several investigators have reported that betaine is especially effective as a supplement in poultry feeding, and that for certain types of rations (those of plant origin) it has a higher supplementary value than either choline or methionine. A possible explanation for this is offered by Dubnoff (5) who presented experimental evidence to the effect that choline must be oxidized to betaine before its methyl groups can become labile and thereby available for transmethylation purposes. This oxidation is accomplished by a choline oxidase enzyme, and Dubnoff's studies indicate that choline is effective only in those animals which have choline oxidase. Since the chick is one of several species said to be lacking in the enzyme which transfers choline to betaine a plausible explanation for the superior supplementary value of betaine in poultry rations is afforded. If there is adequate verification of the concept that choline can function as a methyl donor in metabolic process only after conversion to betaine, it is certain that betaine will assume a status of greatly increased importance as a nutritional factor.

The value of betaine as a methylating agent may well have implications extending far beyond its use as a supplement in poultry feeding. These include alleviation of pathological conditions such as fatty degeneration of the liver and arteriosclerosis. For these and related conditions, administration of choline has shown promising results, according to recent clinical reports, and there is basis for supposing that betaine may also fit into this picture.

Realization of the possible importance of betaine in nutrition and in

medicine is of such comparatively recent origin that much further investigation is required before its full status can be fully understood. It seems possible that the use of betaine as a dietary supplement in poultry feeding may eventually become a leading factor in creating a substantially enlarged market for this by-product of the sugar beet industry.

In addition to glutamic acid, several other amino acids are known to occur in lesser and in varying quantities in beet juice as members of the class of substances which the beet technologists designate as "harmful nitrogen" compounds. The more conspicuous members of this group are aspartic acid, tyrosine, leucine and isoleucine. These amino acids can be recovered from concentrated Steffens filtrate but the method for their isolation in reasonably pure form is extremely laborious, time consuming and costly. There is currently no evidence of any market demand for them at a price commensurate with the cost of their recovery. The "leucine fraction," as isolated from concentrated Steffens filtrate, is unique in that *isoleucine* constitues 50% or more of the total. This is probably the highest ratio of isoleucine to leucine which is encountered in any known biological substance.

Concentrated Steffens filtrate ordinarily contains approximately 14% of non-nitrogenous organic acids based on the weight of its total solids, with varying ratios of volatile and non-volatile acids. Acetic acid constitutes the greater portion of the volatile fraction. These acids are largely of short chain length, being those which escaped precipitation during lime defaction treatment. No commercial value which would justify the recovering of these organic acids has yet become apparent.

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The Other End of the Factory[1]

JAMES D. NORTH[2]

To explain the title I have chosen for my remarks today, I think it would be helpful if we went back and reviewed some of the history of the beet sugar industry; although it may be presumptuous for me to talk about the history of the industry to a group such as this, most of whom have spent their lives in scientific and technological work connected with the growing and processing of sugar beets.

Back in the early days of the industry, when we were first learning how to extract sucrose from sugar beets in this country, there were a great many processing difficulties, and the net result was the processing of a product that was not always uniform in quality and did not always measure up to the cane products in quality. In those days the industry packed and sold the sugar in bulk, and it was consumed by industrial users or it was repackaged into smaller paper bags in the grocery stores.

The pioneers in this industry were men of great tenacity, and no effort was spared to improve the yield and to improve the quality of the sugar taken from the sugar beet. Further than this the leaders of the industry went back of the factory operations to the beet growing process and over the years greatly improved the techniques of beet cultivation and beet harvesting. The results of all of this development work were evident in the quality of the industry's product. The sugar continued to improve to a point where for more than a generation now it has been the equal of cane sugar in every respect. There is no finer sugar manufactured anywhere in the world than the beet sugar processed in the United States. The constant experimentation also resulted in a vastly greater yield of beets per acre and of sugar per ton of beets.

Unfortunately, while all of this tremendous progress was being made by the industry in the technological process, nothing was being said to the consumer to tell the story of this progress; and, as a result, the industry found itself with a real problem at the other end of the factory. This was the problem of taking the sugar to market and selling it effectively and profitably against the existing competition. This problem existed before the war, but when the war came along the problem was pushed into the background; for as you know, there was no difficulty in selling any quantity of sugar that could be produced under wartime conditions. However, after the war had come to a close and sugar production returned to normal, the problem was, in fact, if anything, of greater proportions than it had been before the war.

Something had to be done to help the marketing of the beet sugar industry's product. It was recognized by the leaders in the industry that this problem involved a prejudice against beet sugar which had apparently

[1]Address to the general meeting of the American Society of Sugar Beet Technologists, February 8, 1950, Detroit, Mich.

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stemmed from the time when beet sugar was not the uniformly unexcelled product that it is today. The industry appointed a committee of sales executives to study the problem and come up with a recommendation to management. This committee of sales executives in turn called in various marketing counsellors, advertising agencies, and others to hear their suggestions and recommendations.

Ultimately the committee decided, and management concurred, that the first thing which had to be done was to conduct a broad marketing study to determine the size and extent of the problems which were hindering the industry's marketing of beet sugar. Foote, Cone & Belding of San Francisco was appointed as agent of the industry to conduct this study. The study itself required a little over seven months of work and was probably one of the most comprehensive marketing studies ever conducted for a single industry.

Because of the controversy involved in the beet-versus-cane sugar question, it was recognized that questionnaires returned by mail could not be relied upon because of the inaccuracy of the sample which would go into the calculation of the final conclusions. Therefore, one of the time-consuming and expensive, but vitally important, phases of this study was the use of the personal interview technique. Personal interviews by field investigators were made through the 22 western states, which is the natural marketing area for the western beet industry; and interviews were completed with more than 5,000 housewives and more than 1,000 retail grocers; plus an independent audit of 3,000 additional retail grocery stores, hundreds of jobbers, chain store operators, sugar brokers, industrial sugar users, institutional sugar users, home economists such as newspaper food editors, teachers, home demonstration agents—in short, the entire area wherein people by reason of their thought or actions have an influence on the purchase and consumption of sugar for use in the home.

After all of these data were gathered and reduced to punched cards, we began our analysis, and the results began to point to a plan. We have not time today to go into the details of the findings of this study, but we did get accurate and correct measurements of the different phases of the problem of how much prejudice exists, where it exists, and where it does not.

A plan of operation began to suggest itself from the findings, and it was a plan to overcome unfair competition. We found that beet sugar was being seriously hurt by a very insidious form of unfair competition. It was not the kind of unfair competition which can be eliminated by enforcement of an existing law or the enactment of a new law, for it was not competition resulting from the action of our competitors—it was an unfair competition resulting from the lack of action of the beet sugar industry over a period of many years. They had hidden their light under a bushel, with the result that prejudices and old wives' tales and lack of understanding kept the consumers of the country from purchasing the product and kept the grocers of the country from handling the product so that it could be purchased by consumers.

This problem was recognized to be industry wide. It was not a problem that could be licked by one company. Accordingly the western beet sugar industry decided to set up an operating organization to conduct a broad, educational advertising and merchandising program to eliminate for all time this unfounded prejudice against our product.

Western Beet Sugar Producers, Inc., a non-profit corporation organized under California state law, came into being in July, 1949. All eleven members of the western beet sugar industry, every producer west of the Mississippi River, is a member of the new corporation. And to show you the importance which is attached to the work which must be accomplished by this new group, I would like to read a list of the directors:

Frank A. Kemp, President, Great Western Sugar Company
W. N. Wilds, President, American Crystal Sugar Company
Merrill E. Shoup, President, Holly Sugar Corporation
Reginald S. Carey, President, National Sugar Manufacturing Company
Russell T. Tutt, Vice President, Garden City Company
D. W. Love, Vice President, Utah-Idaho Sugar Company
A. E. Benning, Vice President, Amalgamated Sugar Company
James E. Ellison, Vice President and Manager, Layton Sugar Company
Thomas Heath, Vice Pres. and General Mgr., Franklin County Sugar Company
Roland Tognazzini, President, Union Sugar Company
Carl Moroney, President, Spreckels Sugar Company

In addition to the board of directors there has been established a planning committee to which the directors have delegated authority and responsibility for the development of specific operating plans to accomplish this tremendous job. The planning committee is in essence the same committee of top sales executives as was responsible for the original survey.

San Francisco was selected as the headquarters point, and we have opened offices and our consumer service kitchens at 2 Pine street in that city. The actual operating organization will be kept small. There are three principal functional groups within the new organization. First, there is advertising—and this includes the formal type of advertising addressed to consumers and to the grocery trade and involves the use of the accepted advertising media such as newspapers, radio, outdoor posters, magazines, and the like.

The second functional group is that of consumer service. We consider this to be an extremely important phase of our program, for it involves the development and dissemination of all types of service material aimed toward influencing the housewife to actions which will ultimately be favorable to our industry's product.

The third functional group is called merchandising. This includes the vast and intricate operations in grocery trade relations and the acquisition and maintenance of the grocery trade's acceptance of beet sugar.

I would like to dwell for a moment on each of these three phases in an effort to give you some insight into the type of operation which is planned for Western Beet Sugar Producers. First, let us look at advertising. There is nothing mysterious about advertising, although it has a variety of reputations in these United States. Advertising is simply a specialized form of selling.

When a customer in the Middle West is in the market for a $250,000 installation of grain elevator belting, companies which manufacture grain elevator belting can afford to send two or three highly trained technical men to try to sell their brand and get the order. These men might spend two or three months of their time exclusively in this selling job. However, when General Foods wants to sell a package of Jello for seven cents to a housewife in the same community, it is certainly not an affordable proposition to send even one salesman into the prospect's kitchen to try to sell her Jello in preference to other brands of fruit-flavored gelatins.

However, there are sales tools available, and tools that are affordable, to meet this kind of specialized selling requirement. They are called advertising, but this is simply the use of a vehicle such as a magazine which goes into a consumer's home and carries the message about the product that is to be sold.

In our advertising we intend to get this unfounded prejudice against beet sugar out into the open and talk about it. It has been cloaked in a veil of mystery for too long a time, which has been a contributing factor in playing into the hands of competition. We not only intend to talk about prejudice, but we intend to attack it with the truth and thereby kill it off once and for all. We are going to sell the quality of beet sugar. We are not going to be afraid to call it beet sugar. And we are not going to be afraid to compare it with cane sugar. Beet sugar is second to none, and we are everlastingly going to say just that.

In later phases of the program we are going to sell hard the importance of beet sugar—the importance of this vast industry to the agricultural economy of the great irrigated West. At the present time we are using daily newspapers to tell our story. We may, and probably will, in the future use other advertising media such as radio or the magazines or the comic strips or Sunday newspapers. The media will be selected based upon the requirements of the problem at the time.

Let's look now at the plans for the consumer service department. We are fortunate in having secured as our consumer service director the services of a highly trained and very capable person. Miss Irene McCarthy came to us after twelve years with Safeway stores where she was in charge of the Hallmark Testing service. Miss McCarthy is a graduate home economist from the University of California and took her master's degree in foods and nutrition at the University of Iowa. She served her dietetic internship at the medical school at the University of Iowa and is a member not only of the Home Economics association but of the American Dietetics association and of the Institute of Food Technologists.

Miss McCarthy has as her assistant, and as our kitchen technician, Miss Shirley Vollmer, also a graduate home economist who has had a variety of experience in professional work.

One of the important requirements in any consumer service operation is to establish a professional reputation for the department or group. Much of the success of a consumer service operation depends upon the cooperation

of other professional home economists. In addition to going out and getting top caliber professionals like Miss McCarthy and Miss Vollmer, we have established at 2 Pine street a workshop for the Consumer Service department which I think is as fine as any on the Pacific coast. I wish you could all visit the kitchens in San Francisco, but lacking that I have brought along a few slides to show you the type of layout and equipment which we have available for this important work (slides shown).

The functions of the Consumer Service department can probably be classified under four headings. First, there is the matter of quality control of the industry's products. The industry has recently formed a committee on standards, and the kitchen will be available to assist in testing the industry's products from the housewife's point of view. You people are concerned with laboratory testing of products. The Consumer Service department will provide an additional facility for testing from the point of view of what Mrs. Housewife expects and will insist upon.

Secondly, the kitchens are available to the member companies for testing in the development of new products. As you know, the industry is bringing out specialty sugars, and we have assisted several member companies by putting the proposed product through a series of tests, comparing it with the existing competition and always judging from the point of view of what Mrs. Housewife wants and expects.

In addition to these two types of testing services, the kitchens will develop material to be distributed to the home economists throughout the country. The home economist groups are highly specialized professional people who might be classified as thought leaders, who in their everyday work mold the thinking of the housewives across the country. These are the food editors of newspapers and magazines; radio commentators; teachers; home demonstration agents; and that vast group of home economists in business such as Betty Crocker for General Mills, Frances Barton for General Foods, Aunt Jennie for Lever Bros., and so on.

We will develop material which goes out to these people which will assist them in doing their job. Of course, this material will carry the truth, and nothing but the truth, about beet sugar.

The further broad classification of activities in the kitchens is the development of service material which will be distributed direct to the consumer. This material takes the form of recipe books and leaflets, kitchen cookery hints, and all types of helpful information which will assist the housewife in doing her homemaking job. Much of the material, of course, is distributed via our own consumer advertising.

Turn now to merchandising for a minute—the third department of Western Beet Sugar Producers. Here again we have fortunately gotten an extremely well-qualified person to direct the department. Bill Dugan is our merchandising director and comes to us with a great deal of experience in sales and merchandising of food products.

It is impossible to overestimate the importance of the grocery trade when you have a food product to sell. If we can't get the interest and

cooperation of the grocery trade, from the broker down through the jobber or chain buying office, and right through to every last retail store where the housewife buys her groceries—without their cooperation and support we can't take our product to market. A condition which exists as determined by our original survey is that a great many operators in the grocery trade still think about beet sugar the way they did before the turn of the century. They don't want to carry it because they think their customers won't buy it, and they are not willing to put it in stock to find out. Changing their minds is going to be a long tough job, but it can and will be done because the quality of our product justifies this recognition and support.

We will have in the merchandising department a small group of specialized field merchandising managers whose job it will be to carry the message of our program to all levels of the grocery trade. These men will cooperate closely with the sugar brokers and their member companies' sales personnel. We do not wish to imply in any way that the field merchandising force will replace the sales forces of the sugar companies. We will merely be the representatives of the industry-wide program and will provide the link between that program and the normal staff of brokers and salesmen who sell the individual brands of beet sugar.

In addition to their grocery trade work, the field merchandising managers will do special public relations and sales promotion jobs, working with Parent-Teacher associations, civic and service clubs, and also with the various advertising media which we are using in the various markets.

That is an all too brief summary of the organization and the aims and objectives of Western Beet Sugar Producers. The justification for this broad industry-wide effort is certainly not necessary for this group today. The beet sugar industry is so large and so important in this country that there can be no question of the justification of eliminating a completely unfounded prejudice against a 100 per cent American agricultural product. This job will not be accomplished easily or soon. It will take a long time to undo the state of mind that has taken so long to build up. However, the industry is determined that it will be done. I think the pictures you saw today of our Consumer Service kitchens will indicate that the industry is behind this thing to the finish.

Although the natural marketing area for beet sugar is the 22 western states, our big guns will be trained upon certain sections of the western states in the early stages of the campaign. There are certain areas—notably the vast Rocky Mountain area—which will not receive as great pressure as the areas where beet sugar is not so well known or understood.

Everyone connected with the industry can help in this program. That seems like a weak statement to make, but actually this program and our objectives are somewhat different from most advertising operations. The story we have to tell about the unsurpassed quality of beet sugar is so completely and absolutely true, and can be proved by quoting any authority you care to name, that a little bit of personal selling of this story goes a long way. All of us in the industry are too prone to let George do it. I can

give you a lot of examples about the importance of never missing an opportunity to talk about the quality of beet sugar and to insist upon its proper recognition. I will just give you one.

Recently our field merchandising manager for Southern California was calling on some top grocery operators in Santa Barbara. Santa Barbara is a part of a very large sugar beet producing area. He reported—and we have all of the names and addresses, but they are not important to make the point—he reported that some of the grocery operators in Santa Barbara told him that it was not necessary for them to carry beet sugar because most people were satisfied with cane, and even the big sugar beet growers who were his customers were willing to buy and use cane sugar.

It would take only a few people insisting to the manager of a grocery store to cause him to stock beet sugar, and I would like to sign up every one of you in this room this afternoon to be salesmen for Western Beet Sugar Producers. You can help us solve the problem at the other end of the factory, even as you have collectively solved the problems leading up to and through the factory, by never missing an opportunity to tell the story of beet sugar and particularly to tell the story in the grocery stores where you buy your groceries.

Report of the Secretary

The active paid-up memberships in the Society are distributed as follows:

INDIVIDUAL

United States			
Arizona	3	Nebraska	6
California	84	New Mexico	2
Colorado	61	New York	7
Connecticut	1	Ohio	2
Idaho	23	Oregon	3
Illinois	6	South Dakota	2
Iowa	2	Utah	39
Kansas	2	Washington	3
Louisiana	1	Washington, D. C.	1
Maryland	2	Wisconsin	2
Massachusetts	1	Wyoming	8
Michigan	19		
Minnesota	6		
Montana	17	TOTAL FOR U. S.	297
Others:			
Belgium	1	Ireland	3
Canada	18	Sweden	1
Denmark	4	Uruguay	2
Haiti	1		
Hawaii	1	TOTAL FOR OTHERS	37
		COMPANY MEMBERSHIP	1
		GRAND TOTAL	335

These figures show a loss in individual memberships since the last General Meeting of 32 within the United States and a gain of 11 outside the United States.

The proceedings of the 1948 meeting were published and distributed in May of 1949. Copies were sent to all active members of the Society as well as being sold to 43 parties in the United States, 5 in Canada, 21 in Europe and 5 in other countries. Nine were sent out either gratis or on exchange basis in the United States, 12 in Europe and 2 in other countries.

Surplus copies of the 1942 Proceedings were distributed gratis to the following high schools for reference work in Vocational Agriculture classes:

California	55	Michigan	44	South Dakota	2
Canada	25	Minnesota	18	Utah	35
Colorado	33	Montana	12	Washington	11
Idaho	36	Nebraska	15	Wyoming	12
Iowa	11	Ohio	20		
Kansas	2	Oregon	11	TOTAL	342

There are now on hand in the Secretary's office the following Proceedings and other publications of the Society:

1937 Proceedings	1
1938 Proceedings (Salt Lake City Meeting)	7
1940 Proceedings, Part I (Denver Meeting)	99
1940 Proceedings, Part II (Denver Meeting)	99
1941 Summary of Sugar Beet Investigational Work in Canada and U. S.	50
1942 Proceedings (Salt Lake City Meeting)	97
1944 Regional Proceedings (Detroit Meeting)	3
1946 Proceedings (Denver Meeting)	263
1947 Regional Proceedings (Detroit Meeting)	27
1947 Regional Proceedings (Salt Lake City Meeting)	21
1948 Proceedings (San Francisco Meeting)	343
1949 Regional Proceedings (Detroit Meeting)	2

A library for the American Society of Sugar Beet Technologists has been set up in the office of the Secretary-Treasurer at Fort Collins. This library includes some 50 books on agriculture and factory operation of sugar beets. These books were made available through the courtesy of Mr. Dan Gutleben of San Francisco. Lists were mailed to all members on December 31, 1949, giving names of these books as well as magazines and other publications in this library.

Respectfully submitted,

February 8, 1950 HARVEY P. H. JOHNSON, *Secretary.*

Report of the Treasurer

I herewith submit the Treasurer's report covering the 2-year period, January 1, 1948, to December 31, 1949:

Receipts		
From 1948 General Meeting (Inc. registrations, misc. purchases, etc.)	$1,029.28	
Individual memberships for 1946-47 biennium	5.00	
Individual memberships for 1948-49 biennium	340.00	
Individual memberships for 1950-51 biennium	12.00	
Company membership for 1948-49 biennium	25.00	
Sales of Proceedings (plus postage)	1,338.56	
	$2,749.84	
Balance on hand Decembr 31, 1947	635.59	
TOTAL RECEIPTS		$3.385.43
Disbursements		
On expense of 1948 General Meeting	$ 431.33	
On expense of 1950 General Meeting	13.26	
Purchase of 1949 Regional Proceedings 75 copies of Eastern U. S. and Canada	112.50	
Stationery and Printing	133.11	
Postage (inc. general correspondence, mailing notices and Proceedings)	351.90	
Express on sending out Proceedings	6.93	
Express for transfer of records from Sheridan	72.47	
Stenographic services (Vera Pratt at Sheridan)	103.20	
Office supplies (including new file cabinet)	137.28	
Miscellaneous (inc. membership in International Congress of Agricultural Industries, library books, bank charges, refund of overpayment of dues, etc.)	27.79	
TOTAL DISBURSEMENTS		$1,389.77
Balance on Hand, December 31, 1949		$1,995.66

Respectfully submitted,

February 8, 1950 HARVEY P. H. JOHNSON, *Treasurer.*

Report of Resolutions Committee

BE IT, AND IT IS HEREBY RESOLVED, that a vote of thanks and appreciation be given all those who have made this Sixth General Meeting an outstanding success. Special acknowledgment is due the following:

1. Our outstanding President and hard-working and efficient Secretary, and all other officers and the Advisory Council.
2. General program chairman, E. J. Maynard, and the five sectional chairmen to whom credit is due for an excellent program.
3. General arrangements committee, composed of Perc Reeve, A. A. Schupp, Grant Nichol and Glenn Larke for the performance of the multitudinous tasks connected with providing suitable rooms, equipment and entertainment for this group.
4. Herbert Bush and those who so ably assisted him with the registration duties.
5. Dr. H. Rietberg, Dr. E. C. Stakman, Mr. Geoffrey S. Childs and other guest speakers for their contribution to this program.
6. Glenn Larke for his splendid efforts in handling the publicity.
7. The management of the Statler Hotel for the fine cooperation and for contributing meeting rooms free of charge.

It is the sad duty of the Resolutions Committee to report the death of six of its esteemed members—

HAROLD DUKE BROWN
W. E. NICHOLOY
RAYMOND G. LARSON
CHARLES L. PIODA
GEORGE O. REED
NELSON E. REYNOLDS

A brief sketch of the accomplishments of these members is incorporated in this report and the Committee hereby requests that copies of same be sent to the next of kin with an expression of sincerest sympathy from this organization.

This report was moved and adopted by the Society.

C. E. CORMANY, *Chairman.*

February 8, 1950
Detroit, Michigan

In Memoriam

HAROLD DUKE BROWN

1893 - 1949

Harold Duke Brown was born in Toronto about 1893 and received his primary and secondary education in Toronto and Brampton, Ontario. He got a B.A. Degree from Toronto University, an M.Sc. (Agr.) from Cornell. He took a special course at Edinburgh University, Scotland, and got his Ph.D. from Cornell, specializing in soil technology, genetics and plant building. He went overseas with the Canadian Artillery during the first World War and held the rank of Captain in 1918. He taught school at Flesherton High and Sarnia Collegiate Institute and was associate professor of biology at West China Union University.

He came to Canada and Dominion Sugar Company in 1930 as head of the Agricultural Research Department and from 1941 to 1944 he also held the position of Agricultural Superintendent. He left in 1944 to go with UNNRA, first at Washington and later at Shanghai, China.

He was quite an athlete, being especially good at tennis. He was a member of the Chatham Board of Education for five years and had been a member of the Chatham Rotary club for a few years before he moved to Washington.

RAYMOND G. LARSON

1895 - 1949

Raymond G. Larson, Nyssa-Nampa district manager of the Amalgamated Sugar Company, died suddenly of a heart attack at Nyssa, Oregon, November 26, 1949. He had been a member of the American Society of Sugar Beet Technologists for many years.

Mr. Larson was born near Fairfield, Iowa, March 31, 1895. He was graduated from Oregon State College at Corvallis in the Class of 1920. After graduation he taught general agricultural courses to returned veterans of World War I for the Veterans' Rehabilitation Bureau. From 1923 to 1938 Mr. Larson was county agent of Lake and Malheur counties in Oregon.

In 1938 he became affiliated with the Amalgamated Sugar Company at Nyssa as assistant district manager and became district manager the following year. Larson was largely instrumental in building a substantial sugar beet acreage in the famed Boise valley country and was a pioneer in the industry in this section of northwestern United States. His loss is felt keenly by our Society.

W. E. NICHOLOY

1885 - 1949

The sudden passing of W. E. Nicholoy came as a great shock to everyone in the American Society of Sugar Beet Technologists, and leaves an empty space in the industry that will not readily be filled. He was born May 6, 1885, at Newark, New York, and spent much of his early life in the State of New York.

The late Mr. Nicholoy was president of the Scott Viner Company and was very instrumental in the development of mechanical harvesting of sugar beets. "Nick" was well liked and respected by all who came in contact with him and will be missed by many people for a long time.

CHARLES L. PIODA

1870 - 1949

When Charles L. Pioda passed away on January 18, 1949, the American Society of Sugar Beet Technologists lost one of its original members and staunchest supporters.

Mr. Pioda served the beet sugar industry for 49 years, being first employed with the Spreckels Sugar Company in 1896 as Civil Engineer in charge of irrigation, railroads, and agriculture, and later as Agricultural Superintendent, becoming Resident Manager at Spreckels, California, in 1919, which position he held until his retirement in 1945.

He was extremely proud of the award he received from the American Society of Sugar Beet Technologists in honor of serving the beet sugar industry for more than 40 years.

Mr. Pioda was also extremely active in civic affairs and upon his retirement and again at the time of his death the newspapers in the area lauded not only his service to the industry and his public spiritedness, but also the time and devotion spent in furthering agriculture in general. He was a pioneer in the development of irrigation in the Salinas valley of California, as prior to the development of irrigation in that area the land was largely dry farmed. He made surveys, prepared irrigation layouts and constructed wells, laying the foundation for the irrigation development of that fertile agricultural area.

GEORGE O. REED

1893 - 1949

With the death of George O. Reed, the American Society of Sugar Beet Technologists and his many friends within the sugar industry lost a true friend and a sincere, conscientious worker.

Mr. Reed was born in Hancock County, Ohio, November 22, 1893. He graduated from Findlay High School in 1912 and from the College of Agriculture of Ohio State University in 1915. He served as County Extension Agent in Ohio for several years.

In 1924, he entered the employ of the Great Western Sugar Company. He was a fieldman in the Brush-Ft. Morgan district for a number of years. In 1924, he was appointed assistant manager in those areas. In 1945, he was made manager at Ovid and in August of 1948 he was appointed manager at Sterling. He died in Denver on May 2, 1949.

George Reed was a loyal, sincere, helpful friend to all who knew him. He was loved and respected by his many friends in business and in every day life. He was a sincere counsellor to younger men who worked with him and came to him for advice and information. His ideas and recommendations were accepted and practiced by his associates, many of whom had had more years of experience in their chosen field. He lived his life for his family and his fellowmen. His untimely death left a void among his friends and also in the sugar beet industry which will be difficult to fill.

NELSON E. REYNOLDS

1893 - 1949

The sugar beet industry lost a staunch advocate of mechanical harvesting of beets in the sudden death of Nelson E. Reynolds, a resident of Greeley, Colorado. Mr. Reynolds for ten years had been agricultural engineer for Harry Ferguson, Inc., of Detroit, Michigan, in the development of a mechanical beet harvester. His mechanical engineering training was at Carnegie Institute of Technology and he had many years of practical experience in the implement field, operating the Farr-Reynolds Implement Company of Greeley which handled International Harvester machinery. Mr. Reynolds always insisted that the sugar beet tops should have equal importance in the development of a harvester along with the roots and was working on some very original ideas at the time of his death, which occurred rather suddenly while he was on a fishing trip in Wyoming.

Mr. Reynolds is survived by his widow, Mrs. Gladys Reynolds; two daughters, Mrs. Barbara Romsdal of Fort Collins, Colorado, and Mrs. Mary Frances Frazier, of Denver, Colorado; his mother, Mrs. Mary Reynolds of East Lansing, Michigan; his sister, Frances Reynolds of New York City, and a brother, Burrell Reynolds, of Grand Junction, Colorado. His death occurred in July, 1949. He was 56 years old.

FORTY-YEAR SERVICE AWARDS

The American Society of Sugar Beet Technologists presents certificates of appreciation to its forty-year veterans of faithful service to the beet sugar industry of America. These men have seen the industry grow from a struggling infant to a place of honor among the most useful industries of the nation. They have, through the untiring labor of their own hands, in the ideas they have contributed and by the inspiration of their courage, diligence and faith in the future, played an important part in the development of the industry which in turn has proudly presented them with Certificates of Appreciation. These certificates have been presented at the regular biennial meetings since 1946. The following have been recipients of the awards:

1946

CARL D. ADAMS, Holly Sugar Corporation
G. M. BRADFORD, Monitor Sugar Company
J. W. BRESSLER, American Crystal Sugar Company
PHIL DALE, Great Western Sugar Company
G. J. DALEY, Woodland, California
A. J. DENMAN, American Crystal Sugar Company
H. C. GIESE, Great Western Sugar Company
A. M. GINN, Great Western Sugar Company
A. H. HELT, Great Western Sugar Company

R. L. HOWARD, Utah-Idaho Sugar Company
FRANK S. INGALLS, Utah-Idaho Sugar Company
MORONI JENSEN, Utah-Idaho Sugar Company
H. J. KLINGE, Franklin County Sugar Company
W. L. LAWSON, Holly Sugar Corporation
N. R. MCCREERY, Great Western Sugar Company
SIDNEY J. OSBORN, Great Western Sugar Company
CHAS. L. PIODA, Spreckels Sugar Company
DOUGLAS SCALLEY, Utah-Idaho Sugar Company

W. D. SCHARTON, National Sugar Mfg. Company
W. F. SCHMITT, Great Lakes Sugar Company
EUGENE STOECKLY, Garden City Company
FRED G. TAYLOR, Utah-Idaho Sugar Company
HENRY A. VALLEZ, Isabella Sugar Company
F. A. WILSON, Great Western Sugar Company
C. R. WING, Canadian Sugar Factories, Ltd.
T. GEORGE WOOD, Canadian Sugar Factories, Ltd.
H. E. ZITKOWSKI, American Crystal Sugar Company

1948

T. E. GARDINER, Holly Sugar Corporation
AUGUST LUDWIG, Superior Sugar Refining Co.
B. O. MCCULLOCH, Amalgamated Sugar Company
J. W. ROONEY, American Crystal Sugar Company
H. J. SANDERS, Gunnison Sugar, Inc.
L. R. STEWART, Michigan Sugar Company
R. S. STEWART, Union Sugar Company

1950

GEORGE P. WRIGHT, Spreckels Sugar Company
WILLIAM H. PAULSEN, Spreckels Sugar Company
L. J. ARNOLD, Gunnison Sugar, Inc.
H. W. DAHLBERG, Great Western Sugar Company
J. B. BINGHAM, American Crystal Sugar Company
SIDNEY F. SHERWOOD, U. S. Department of Agriculture
HENRY MARTINI, Michigan Sugar Company
D. J. ROACH, Great Western Sugar Company
C. D. BARBER, Menominee Sugar Company

MERITORIOUS SERVICE AWARD

This new award was first presented at the 1950 session. The first and only recipient to date is SAMUEL BENTON NUCKOLS, Agronomist, Division of Sugar Plant Investigations, U. S. Department of Agriculture, who retired on September 30, 1949.

Seed Germination and Preparation

A Continuous Spray-type Seed Treater[1]

ROBERT A. KEPNER[2] AND L. D. LEACH[3]

In recent years most seed treatment has been done by dusting the fungicides upon the seeds in either batch or continuous treaters. This method, however, has not been entirely satisfactory, chiefly because the dusts may be offensive to the operator during treating or to the grower during planting.

The introduction of the slurry treater, the development of the Spreckels batch spray treater (1) (2)[4] and the formulation of wettable fungicides represent real advances in dust elimination. However, there still remains a demand for a continuous seed treater of high capacity which will apply soluble or wettable fungicides to all types of seeds in a uniform manner.

The spray treater discussed in this paper was developed in an attempt to satisfy this demand. After tests on a full-scale experimental unit had shown that seeds could be treated uniformly and effectively with it, a model suitable for commercial production and large-scale operation was designed, and one machine was built for the Holly Sugar Corp. This paper will deal primarily with the tests and operating principles of the experimental unit, but occasional reference will be made to the commercial unit.

Description and Operation

A side view of the experimental unit is shown in Fig. 1. During the tests, two cup-type elevators (not shown) were used to recirculate seed into the hopper when the spray was not being used or to put sprayed seed into bags or into a weighing can on scales. In the operation of the treater, seed is metered into one end of the rotating drum and is spilled out at the opposite end after being treated. Metering of the seed is accomplished by means of a 4½ inch diameter-vaned wheel 14 inches long, which maintains a practically constant volumetric rate at a given rpm. On the inside of the drum is a liner made from sheets of corrugated aluminum roofing (Fig. 2). As the drum rotates, the corrugations carry seed up from the bottom, spreading it over a band about 1 to 2 inches thick, extending from the lowest part of the drum up through an angle of 80 to 100 degrees. The spray material is directed onto this band of seed by a fan-type weed nozzle mounted inside the drum about 2 ft. from the inlet end and 45 degrees down from the top of the drum. The drum was made 3 ft. in diameter so that the nozzle could be placed far enough away from the seed surface to allow good dispersion of the spray before striking the seed. The 6-ft. length of the drum accommodates a standard size of corrugated roofing. The corrugated liner is self-cleaning because of the absence of sharp corners, the flatness of the corrugations with respect to the drum, and the resultant scouring action of the seed.

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[1] This paper prepared for Sixth General Meeting of the American Society of Sugar Beet Technologists, Detroit, Michigan, Feb. 6-9, 1950.

[2] Assistant Agricultural Engineer, Agricultural Experiment Station, University of California, Davis, California.

[3] Plant Pathologist, Agricultural Experiment Station, University of California, Davis, California.

[4] The numbers in parentheses refer to literature cited.

The spray system is the most involved part of a spray-type seed treater and is the part most likely to give trouble in field use, primarily because most of the presently-used treating materials are insoluble powders which must be kept in suspension (usually in water) during application. In order to keep these insoluble materials in suspension, agitation is required in the supply tank, and adquate velocities must be maintained in pipes. The suspended material tends to clog screens and nozzles and may permanently plug small pipes after a shutdown unless the system is flushed. Nozzles must be small because only a very low percentage of moisture can be applied to seeds (less than one per cent maximum on some seeds); yet they and the screens must be large enough to pass the suspended particles of treating material.

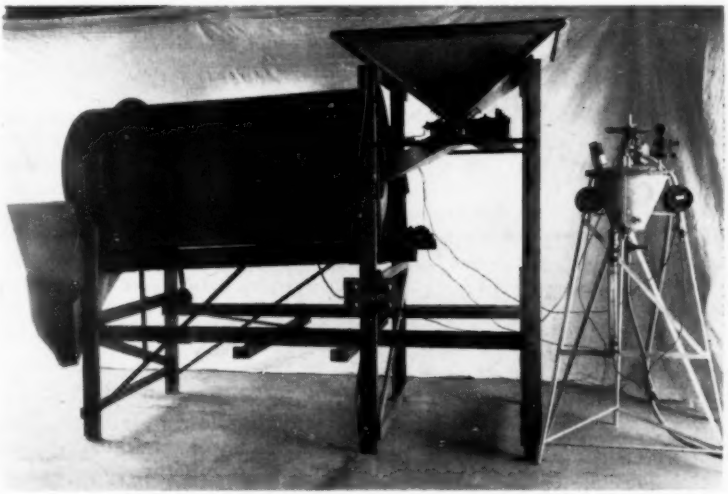

Figure 1. Experimental Seed Treater. Seed hopper is above right end of rotary drum, with seed meter attached to bottom of hopper.

Another problem encountered in connection with the spray system is that of abrasion caused by the suspended particles. Some of the materials are so abrasive that a gear pump will wear out in a few days, and brass nozzles would have to be replaced after only a few hours of operation. Because of the abrasion problem, it was decided to use a pressurized supply tank with the agitator shaft entering from the top, so that no pump would be required and no wearing parts would be in contact with the suspension.

The 5-gallon pressurized tank used with the experimental machine is shown at the right in Fig. 1. The commercial treater has a 25-gallon tank. In regard to nozzle erosion, preliminary checks indicated that stainless steel nozzles are much superior to brass nozzles in this respect (3). Later tests (4) have shown hardened stainless steel nozzles to be even better than ordinary stainless steel.

Performance

The experimental treater was tested for treating decorticated sugar beet seed, milo (grain sorghum) and baby lima beans, under various combinations of drum speed, drum slope, nozzle pressure and seed rate. For all treating runs, a green dye was used in the spray mixture; sprayed seeds were then examined visually and sorted into light, medium and heavily colored groups, using an arbitrary standard of division. In addition, plantings were made in sterile soil or sand to check for injurious effects and in infested soil to measure protection. Preliminary developmental work was carried out with decorticated sugar beet seed because its rough, absorbent outer surface makes uniform distribution of a liquid more difficult than on smooth-coated seeds, such as lima beans.

The maximum rate for satisfactory coverage of sugar beet seed appeared to be about 3,300 pounds per hour. A 2 percent application of moisture was used in most of the beet seed runs, although 4 percent was used in one trial. In treating milo, the only seed rate tried was 6,300 lbs. per hour, using a 1 percent moisture application. With baby lima beans, trials were made with ½ percent moisture added at a seed rate of 8,100 lbs. per hour and with ¼ percent at 11,000 lbs. per hour. Satisfactory coverage was obtained in each case, with no mechanical injury to the seed. In limited comparisons with beet and milo seeds, nozzle pressures of 25 to 28 lbs. per sq. inch appeared to give as uniform coverage as a pressure of 60 lbs. per sq. inch.

With both sugar beet seed and milo, the most uniform application was obtained when the drum axis was about 2 degrees below horizontal. The results of an analytical study of the action on the rotating drum (3) are interesting and useful in understanding the effect of drum slope and of other variables involved. The action of the corrugated liner (Fig. 2) is such that one layer of seed is being carried upward by the corrugations, while a second layer in contact with the first one is moving downward as a result of gravity. Spray from the nozzle strikes those seeds which are at or near the exposed inner surface of the downward-moving layer. If we neglect the effect of turbulence and intermixing between the two layers, it is evident that the probability of a particular seed's being hit by the spray would be a function of the thinness of the downward-moving layer, the size of the seeds, and the number of times a seed passes downward within the longitudinal limits of the spray zone.

Based upon measurements of the total amount of seed in the drum during operation and the total area covered by the seed band, the average total thickness can be computed readily. By further calculations, based on

some rather broad assumptions (3), the thickness of the *downward-moving* portion of the seed layer can be determined in terms of number of seeds, and the average number of times that a seed would pass downward within the spray zone can be "estimated." Table 1 shows the results of these cal-

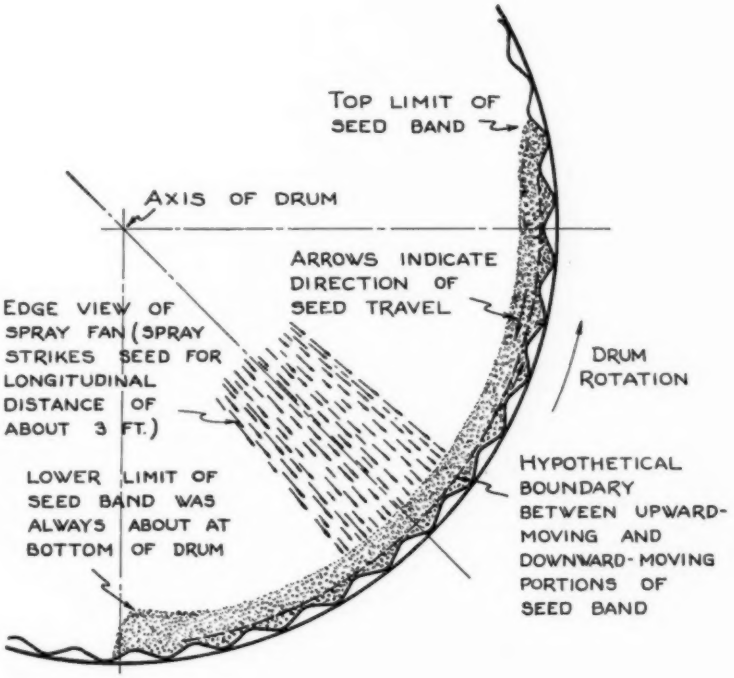
TOP LIMIT OF SEED BAND
AXIS OF DRUM
ARROWS INDICATE DIRECTION OF SEED TRAVEL
EDGE VIEW OF SPRAY FAN (SPRAY STRIKES SEED FOR LONGITUDINAL DISTANCE OF ABOUT 3 FT.)
DRUM ROTATION
LOWER LIMIT OF SEED BAND WAS ALWAYS ABOUT AT BOTTOM OF DRUM
HYPOTHETICAL BOUNDARY BETWEEN UPWARD-MOVING AND DOWNWARD-MOVING PORTIONS OF SEED BAND

Figure 2. A cross section of the rotating drum showing details of its operation.

culations, as well as the results of the color sorting, for one group of runs at various drum slopes, using sugar beet seed. The percent light-colored seeds is an experimental measure of non-uniformity of coverage, while the relative magnitudes of the figures in the two right-hand columns give a theoretical indication of expected uniformity of coverage. For example, changing the drum slope from 1 degree to 2 degrees (outlet end lower than inlet) reduces the layer thickness from 7 to 4 seeds but reduces the possible number of

exposures only from 7.5 to 6.4; thus this change would be expected to improve the coverage. Note that the 2-degree run does show the lowest percent of light-colored seeds, indicating the most uniform coverage.

Table 1.—Uniformity of Coverage as Related to Drum Slope.

Drum slope, degrees below horiz.	Percent light colored seeds	Percent medium colored seeds	Avg. total thickness of seed band, inches	Estim. avg. thickness of downward moving layer, No. of seeds	Calc. Avg. No. of times a seed passes down through spray zone
0	13	87	1.95	13	7.4
1	11	89	1.26	7	7.5
2	5	95	0.83	4	6.4
3	9	91	0.60	3	5.1

Used decorticated sugar beet seed at 53 lbs. per min., with 2 percent moisture added. Drum speed, 25 rpm; nozzle pressure, 60 lbs. per sq. inch.

As a further test of the protection afforded by fungicides applied with the experimental treater, samples from a number of runs were planted in greenhouse flats in soils infected by *Pythium ultimum*, in comparison with non-treated seeds and with dusted seeds. The degree of protection was measured by the emergence and survival of seedlings under conditions extemely favorable for both pre-emergence and post-emergence damping-off. In nearly all cases the spray-treated seeds produced stands significantly higher than non-treated seeds. Because of the limited extent of these trials and the normal variability in this type of test, most of the differences between runs of the spray treater are not statistically significant. However, with sugar beets, the runs which appeared most uniform in the color sorting tended to provide the highest degree of protection. With milo, there were no significant differences in protection between the different spray applications or dusting, but all treated lots showed significantly better emergence than the non-treated seed.

In connection with performance tests of the commercial version of the spray treater (at Holly Sugar Corp., Stockton), additional tests were made using seed from a single lot to obtain a direct comparison between spraying, dusting and slurry treating. Since tests involving all three treating methods were not run in connection with the experimental unit, the results obtained with the commercial unit are included in this paper. With each of the three methods, the treatment was 4 oz. Phygon XL plus 5⅓ oz. 75 percent lindane, per 100 lbs. of seed, applied simultaneously. The slurry treater was operated at about 70 lbs. of seed per min. with 1 percent moisture added, while the spray treater had a seed rate of 52 lbs. per min. with 2 percent moisture added. The commercial spray treater has a fixed drum slope of 2 degrees below horizontal and operates at a drum speed of 25 rpm; the nozzle pressure during these runs was 30 lbs. per sq. inch.

Table 2.—Protection and Uniformity of Coverage on Beet Seed for Three Methods of Treating.

Treating Method	Color sorting results			Seedlings per 100 seed units		
	% Heavily Colored	% Light Colored	% Medium Colored	Pasteurized soil, emerg.	Pythium-infested soil emergence	Pythium-infested soil Survival
Non-treated	0	100	0	164	60[1]	18
Slurry treated	7	35	58	147	97	45
Spray treated	0	3	97	146	127	67
Dusted	—	—	—	140	141	90
Least significant difference, 19:1 odds				n.s.	29	31
Least significant difference, 99:1 odds				n.s.	41	42

[1] Blackface figures indicate significant difference from dusting (99:1 odds)

Table 2 presents the results of the color sorting and the results of the greenhouse tests in Pythium-infested soil. Note that the sprayed sample had only 3 percent light-colored seeds and no heavily-colored seeds, while the slurry treatment gave 35 percent light seeds and 7 percent heavily colored. With some treating materials, the over-dosage indicated on heavily-colored seeds would be injurious to these seeds. In regard to the greenhouse tests (last three columns in Table 2), there were no significant differences in emergence in pasteurized soil, indicating no injurious effects from the treatments. In the Pythium-infested soil, emergence and survival of both the slurry-treated and the nontreated samples were significantly lower than for the dusted sample. Differences between the dusted and sprayed samples were not significant, although the sprayed sample was slightly lower than the dusted sample in both emergence and survival. However, in subsequent tests involving several other lots of beet seed (4), the results favored the spray treatment as often as they favored the dust treatment; in general, they indicated that protection obtained with the spray treater was equal to that obtained by dusting.

Summary

The seed treater discussed in this paper is essentially a high-capacity constant-rate machine and is not particularly suited to the treatment of small lots of seed. The maximum seed rate is determined by the ability of the machine to apply the treating material uniformly. For sugar beet seed, this maximum is probably about 3,300 lbs. per hour. Protection obtained at this rate was equal to that obtained by dusting at the same dosages. The minimum seed rate when applying materials suspended in water is determined chiefly by the minimum size of nozzle which can be used without clogging and by the maximum percentage of moisture which can be added to the seed. A 2 percent application of moisture was used in most of the beet seed runs, although 4 percent can be applied safely.

The principal problems encountered in the use of such a treater are:

(a) ***Clogging of nozzles and screens by suspended materials.*** **Proper selection of nozzle and screen sizes minimizes this problem. The use of soluble or liquid materials and the improvement of present formulations of insoluble materials would also help.**

(b) *Abrasive action of suspended materials.* Pump troubles have been eliminated by use of a pressurized supply tank with the agitator shaft entering from the top. Erosion of nozzles apparently can be kept within reason by use of hardened stainless steel instead of brass.

(c) *Settling of suspended materials in pipe lines.* Overcoming this problem requires the use of small-diameter lines to maintain adequate velocities and involves flushing the lines with air or water whenever the machine is shut down.

The chief advantages of this treater are:

(a) Uniform coverage, even on rough absorbent seeds, such as sugar beets.

(b) Protection of the operator from dangerous or obnoxious materials. (The commercial model is completely enclosed to confine the treating spray.)

(c) Reduction of dust nuisance in subsequent handling of treated seed (as compared to dusted seed).

(d) Ease of complete emptying and cleaning. The drum is self-cleaning, with no corners in which wet seed might stick and accumulate, and at a 2-degree slope will empty itself within a minute or two after the seed supply is stopped.

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Experiences in the Practical Use of a Continuous Spray Treater

L. A. KLOOR[1]

For many years it has been an established fact that in most of the sugar beet producing areas of the United States forms of fungi occur in the soil, which are partly, and sometimes totally, responsible for the loss of seedling stands. Plant pathologists have demonstrated that satisfactory stands can be established in fields where the level of causal organisms is a limiting factor by resorting to careful seed treatments with fungicides (1) (2) (3)[2]. During the past two years another seed treatment has been used extensively in California which has been economical and effective in the control of wireworms. The pure gamma isomer of benzene hexachloride is used in this treatment (4). It can be applied to the seed as a supplementary treatment with a fungicide, or alone.

Prior to the conception of the idea of applying treating materials as suspensions of wettable fungicides, either as a slurry or a spray, the accepted method of application consisted of dusting the seed with dry powder fungicides. In many cases as much as 1 percent by weight on seed had to be used to obtain satisfactory seed protection. Serious repercussions arose as a result of the offensive nature of the treating materials being used. They were a hazard to the health of the operator of the seed treater and of the labor handling the seed in the field. Many processors could not ignore the complaints of labor and discontinued completely the treating of seed. This left no alternate for the grower who had to plant treated seed in order to secure a satisfactory stand. He had to treat his own seed or take the risk of loss of stand. Some small measure of relief was obtained from excessive dustiness when formulations were placed on the market which required as little as 0.25 percent by weight on seed to secure protection.. These products were still powders—they were dusty, obnoxious to handle, and toxic. Furthermore, the average grower's homemade equipment was, and still is, inadequate to cope with the proper, well dispersed application of small volumes of treating materials on large volumes of seed.

The slurry method was a progressive step in the technique of treating seed. Dustiness attendant to the actual operation of the machine was eliminated. However, in runs with a slurry machine it was found that there was poor uniformity of coating with treating materials even when well-decorticated sugar beet seed was treated. Dispersion of materials was inferior to that obtained by spray treating. By the same token it was found that emergence and survival of seedlings in Pythium-infested soil was lower than in the case of seedlings from spray treated seed (5).

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[1] Research Agriculturist, Holly Sugar Corporation, Stockton, California.
[2] Numbers in parentheses refer to literature cited.

The original concept of spray treating sugar beet seed was embodied in a batch spray treater designed by Armer in 1948 (6). A commercial model of a continuous spray type seed treater, designed by Kepner and Leach (5) of the University of California, was constructed by the Blackwelder Manufacturing Company of Rio Vista, California. In design the machine does not differ radically from the experimental model except in the addition of certain operating parts and their locations. Many of the integral parts of the experimental model were, perforce, constructed for temporary use and therefore built of non-permanent materials. The commercial machine is a rugged, well constructed piece of equipment.

A well designed control system is employed which assists the operator in accomplishing a precision job of treating. The entire system, consisting of electric switches, pressure gauges, signal lights, and electric horn, is mounted on a panel board conveniently located at the discharge end of the treater. By means of this installation the operator is kept conscious, at all times, of the following important operating conditions: (a) Seed supply entering the treater; (b) Flow of treating material through the spray nozzle; and (c) Maintenance of mechanical agitation of the suspended treating material in the treatment supply tank. The two first mentioned function automatically. A brief description of the system follows:

The walls of the seed hopper are constructed of light, flexible, galvanized iron. A micro switch has been installed, the plunger of which has been adjusted to a clearance of .005 inch between same and one wall of the hopper when empty. In this no-seed position the seed indicator light circuit is open and the signal horn circuit is closed. This control will function when the supply of beet seed in the hopper has been reduced to approximately 20 pounds. Two 0-60 psi pressure gauges and a pressure differential switch actuate the automatic signal indicating either normal or restricted flow of treating materials through the spray nozzle. One gauge is connected to the inlet end of the tank-to-nozzle feed line and the pressure differential switch. The other is connected to the nozzle and the pressure differential switch. In operating practice, at the required nozzle pressure for a predetermined spray application, experience has shown that a constant differential exists between nozzle and tank pressure when the flow of liquid through the nozzle orifice is not obstructed. It follows, therefore, that any condition causing partial or total clogging of the nozzle would result in partial or total loss of this differential of pressure. Under our specific treatment requirements, this differential is about 8 psi. We have adjusted the pressure differential switch to actuate the signal system when the pressure loss reaches 3 psi. The light and signal horn function just as in the case of seed supply. The third control, which is manually operated, simply consists of a light which indicates whether the spray tank agitator motor is in operation.

When precision spraying with inflexible amounts of suspensions of abrasive materials per given volume of seed is required, nozzle orifice erosion can readily become a serious factor in the application of exact dosages. A flow glass arrangement has been installed in the spray tank system whereby the time of flow, in seconds, of a fixed volume of water can be determined

for the purpose of ascertaining the operating pressure and/or degree of erosion of the nozzle orifice currently being used. The floor plan for the installation of the treater and the equipment therewith, called for fitting the treater into, and making it an integral part of, the exising seed processing equipment. A hopper was constructed near the gravity table so that processed seed could be discharged, if desired, directly into it and transferred by airlift to the treater seed supply tank. Alternatively, seed from selected lots which had already been bagged could be fed into this hopper

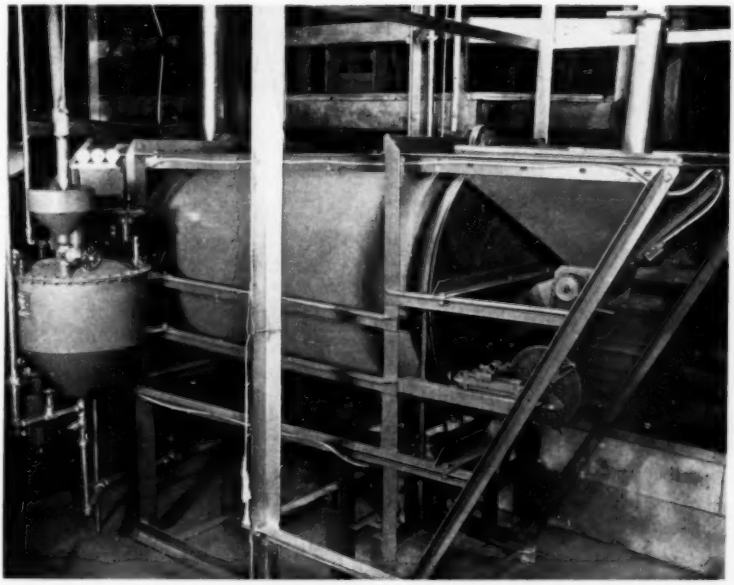

Figure 1. A continuous spray type seed treater.

if it became necessary to draw from a stockpile of processed seed. Since the treater is arranged to discharge treated seed into this same hopper, it follows that the treater seed supply tank cannot be filled during treater operation. When the treater is started, the airlift is made to discharge, by valve arrangement, into the sacking station supply tank. From here the treated seed is bagged-off. Both of the aforementioned tanks have a capacity of 4,000 pounds of seed each.

An airlift elevator was installed instead of the conventional bucket-type elevator for the transferring of seed to and from the treater. It was felt that the following advantages would accrue from this type of installation: (a) Less danger of mechanical damage to the seed; (b) Additional cleaning of seed in the transfer; and (c) Some drying effect on seed from the treater during transfer to the sacking station supply tank. In actual operation we have found that these results have been attained. The installation of a separate airlift to handle the treated seed would be an improvement over the present installation. The advantage of such an installation is obvious.

In the construction of the commercial unit, the treater spray tank was attached to the frame of the machine. All of the necessary connections, electric, water, et cetera, between the integrated parts of the unit were completed by the manufacturer. On installing the machine for operation, we attempted to utilize all of the means possible which made for ease and convenience of the operator. The spray tank was piped so that we could blow all, or unused, portions of the treating materials back into a mixing tank located on the deck above the treater. We make full use of the compressed air piped to the spray tank in all of our flushing-out operations following a run. Convenient sewering connections have been installed from the tank. The extreme overall dimensions of the treater are: Length—10 feet, width—6 feet, and, height—6 feet 8 inches. The actual floor space occupied by the treater and the framework supporting the two seed tanks measures 17 feet long by 14 feet deep. Ample walking space around the machine is included in these measurements.

In the interest of brevity, this paper will not attempt to describe all of the details connected with the operation of the machine. The most important of these will be described.

We are currently using Phygon XL wettable powder (2.3—dichloro—1,4—naphthoquinone) as a fungicide and 75 percent Lindane (from the pure gamma isomer of benzene hexachloride) as a wireworm repellent. These two materials are weighed together in the proper proportions to formulate a predetermined quantity of completed mix, which, when applied at the rate of 2 quarts per hundredweight of beet seed, will give dosage applications of 0.25 and 0.33 percent, on seed, for Phygon and Lindane, respectively. To keep down dust, the materials are slurried immediately after weighing. They are then transferred to a mixing tank where a dye is added and the suspension volume made up to the mark with water. Following several minutes of thorough agitation, the mix is then discharged, by gravity, into the treater spray tank. In its passage into the treater tank the mix is filtered through a 60-mesh screen. The spray tank agitator is started when the mix is being run into the spray tank and is kept running as long as any mix remains in said tank. The tank is pressurized by opening the compressed air supply valve. Previous experience with the nozzle being used and the pre-determined degree of erosion which occurred during the previous run will help the operator to determine the approximate nozzle pressure required to accom-

plish proper treatment at a given flow rate of seed. Knowing from experience the operating pressure differential between tank and nozzle, as indicated by the two gauges, we pressurize the tank accordingly to the desired psi. A diaphragm valve affords accurate rapid adjustment to air pressure. It is necessary to determine the bushel weight of seed prior to making a run so that the proper rotor speed setting of the seed metering device can be made which will give the desired rate of flow.

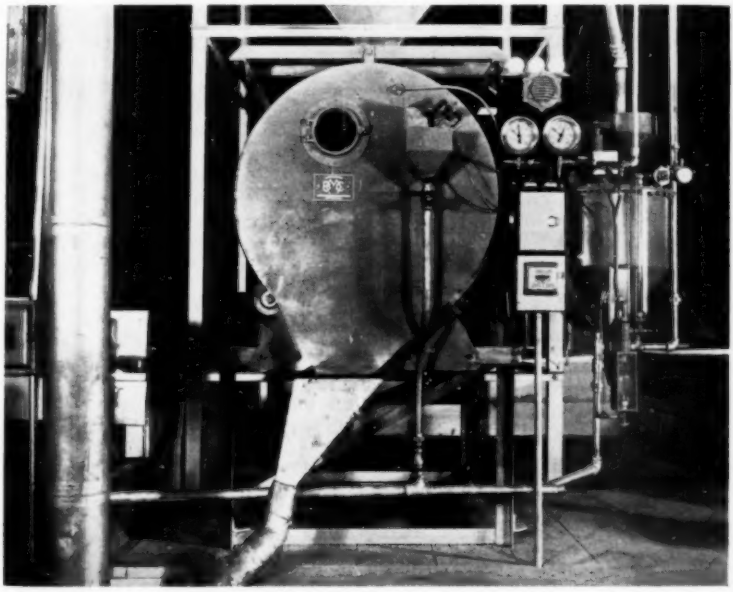

Figure 2. This view shows in more detail the continuous spray type seed treater.

When the machine was first put into operation we encountered numerous aggravating delays from nozzle clogging. This was influenced to some extent by the manner in which we prepared our suspension, but in greater measure by the limited size of the nozzle which had to be used for the application of treating materials at the rate of 1 quart per hundredweight of seed. This condition was corrected by the simple expedient of cutting the concentration of mix to half of that previously used, increasing the nozzle capacity approximately 33 percent, removing the nozzle screen completely, and adjusting the operating pressure and seed flow rate to the application of 2 quarts of mix per hundredweight of seed.

Some serious nozzle erosion threatened to interpose a problem. This was corrected in the early stages of operation by substituting hardened stainless steel nozzle tips for the conventional stainless steel tips first used. Stainless steel tips had to be discarded after treating 7,000 pounds of seed. With hardened stainless steel tips, we have treated as much as 43,500 pounds with a single tip.

The flow rate of seed can be controlled over a wide range with the seed metering device. We have treated beet seed at the rate of 3,120 pounds per hour when applying mix at 1 quart per hundredweight of seed. For our purposes we have found that rates of flow in excess of 50 pounds per minute are not practical. We, therefore, add the maximum allowable amount

Table 1.—Protection Obtained with the Continuous Spray Treater as Compared with Dust Treatment.

Seed Lot and Treating Method	Seedlings per 100-seed Unit		
	Pasteurized Soil	Pythium-infested Soil	
	Emergence	Emergence	Survivors
U.S. 56, lot 108			
Nontreated	164	**50**[4]	**7**
Spray treated[1]	183	147	88
Dust treated[1]	----	149	61
U.S. 15, lot 134A			
Nontreated	175	**58**	**11**
Spray treated[1]	172	144	97
Dust treated[1]	----	152	102
U.S. 15, lot 134B			
Nontreated	158	**78**	**19**
Spray treated[1]	151	*137*	90
Dust treated[1]	----	153	102
U.S. 15, lot 136			
Nontreated	170	**58**	**10**
Spray treated[2]	160	145	**110**
Dust treated[2]	----	128	67

[1] Combination treatment, using 4 oz. Phygon XL and 5⅓ oz. 75% Lindane per 100 lbs. of decorticated beet seed.
[2] Treated with Phygon paste at 4 oz. per 100 lbs. of seed.
[3] Treated with Phygon XL at 4 oz. per 100 pounds of seed.
[4] Blackface figure indicates significant difference from dusting (blackface is for 99.1 odds and italic is for 19:1 odds).

of moisture (approximately 4 percent) with a nozzle size approaching that which would give least interruption from clogging. We have obtained very satisfactory treatment with seed flow rates in the neighborhood of 40 pounds per minute. This is about the rate at which we now generally treat our beet seed.

All of our seed is dyed during the process of treating. We make use of dyes for purposes of observing the uniformity of distribution of treating materials, and identifying the particular kind of seed treatment. Green is used to identify repellent-fungicide treated seed; red to identify repellent-treated seed; and yellow to identify fungicide-treated seed. The dyes used are neutral water soluble materials. Excellent coverage is obtained with the spray treater using 3 grams of dye per hundredweight of seed. A concentrated

solution of dye is added to the suspension of treating materials before completing the mix to the desired volume.

It has been observed that when 2 quarts of suspended treating materials (approximately 4 percent moisture on seed) are applied, some apparent swelling of seeds takes place. Bushel weight determinations on 30 lots of seed before and after treatment indicate an average loss of 1.40 pounds per bushel after treatment. Screen tests verify this increase in seed size. There was a significant increase in the percentage of seed remaining on the 9½/64 inch screen (processed size 7-9½/64 inch) after treatment. All seed, however, passed through the 10/64 inch screen.

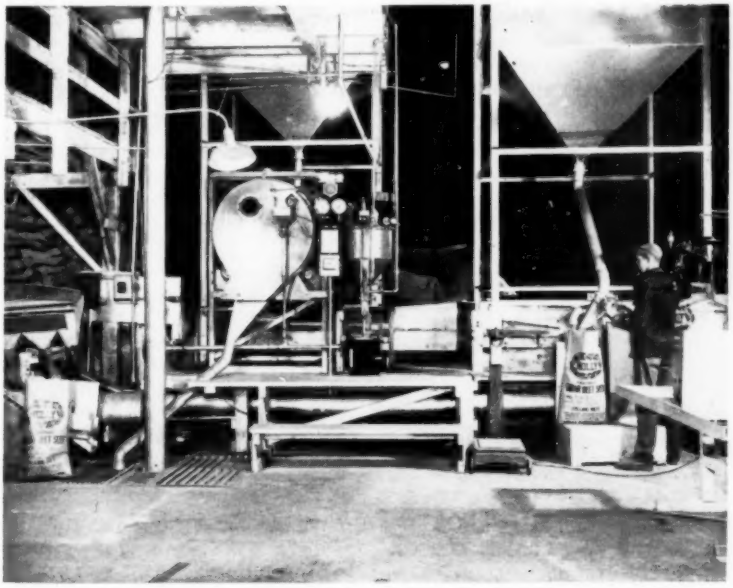

Figure 3. A commercial model of a continuous spray type seed treater in action. This view shows how the installation was worked out in a plant.

Numerous greenhouse germination trials have been completed, using samples of seeds taken from many of the lots which were treated with fungicides applied by the continuous spray treater. In the majority of cases, spray-treated seeds gave significantly higher stands than non-treated seeds in Pythium-infested soils. In general, there were no significant differences in emergence and survival counts between carefully dusted and spray-treated seeds. Some of the results are set forth in Table 1.

Summary

The Continuous Spray-Type Seed Treater is essentially a high volume machine capable of applying with positive precision, both as to uniformity and quantity, suspensions or solutions of treating materials.

The degree of accuracy, and by the same token the degree of protection, obtained in seed treatment will depend upon the skill and conscientiousness of the operator. Trustworthy seed treatment is paramount and all other considerations, within reasonable limits, are unimportant. A skilled operator should be employed to treat seed with this machine.

The requirements for installation of a continuous spray treater are such that the equipment can easily be fitted into the production line of any well arranged seed processing plant. Since the machine has a practical operating capacity of about 2,500 to 3,500 pounds of processed beet seed per hour, it is obvious that storage supply tanks become a desirable part of the installation. In like manner, an elevator, preferably airlift, capable of taking away the full output of the treater should be installed.

Mechanical troubles have been few and unimportant. There are no complicated parts to the treater and all are accessible for maintenance and repair. Service requirements are nominal. The drum is self-cleaning.

The high capacity and cost of the machine limit the possibility of its coming into general use by other than large seed processors.

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Three Years' Experience with Batch Spray Treating of Beet Seed

RALPH S. LAMBDIN[1]

The Spreckels Sugar Company has processed and spray treated more than one and one-half million pounds of seed during the past three seasons. This accomplishment is a testimonial to a cooperative development program which combined the efforts and ideas of Experiment Station specialists, mechanical engineers and the too often unpraised operators of seed processing stations. Experience had proved that growers were doing an unsatisfactory job of seed treating with makeshift equipment in the field. Dust treating, prior to issuing seed at a central point, creates a dust hazard and most fungicidal materials are either toxic or skin irritants.

Preliminary experiments, conducted jointly with the Plant Pathology Division of the University of California, indicated the feasibility of spraying fungicides on beet seed and possible elimination of many of our seed treating problems. Dr. L. D. Leach[2] contributed the pioneer work in proving the effectiveness of fungicide suspensions sprayed onto sugar beet seed.

The original spraying equipment, which consisted of two Batch Spray Treaters, one installed at Woodland, California, and one at Spreckels, California, was designed by A. A. Armer[3]. Some minor alterations have been made each season to improve our seed coverage and to reduce clogging of nozzles. In order to make improvements as rapidly as possible different approaches have been used at each plant with the same objectives in view. At the Woodland plant improved seed coverage has been obtained by slightly changing the shape of the mixing drum and adding a third nozzle to the spray manifold (Fig. 1). Increasing the speed of the spray pump has provided an optimum pressure range.

The changes at the Spreckels plant consist of one additional nozzle on the spray manifold and complete elimination of the pump by use of a compressed air supply to maintain the desired pressure on the spray liquid (Fig. 2).

The materials used in the batch spray application of fungicides were developed by the U. S. Rubber Company's Naugatuck Chemical Division. Continued improvement by this manufacturer of his product has eliminated earlier objections to characteristics of abrasiveness and inability to remain in suspension. The product now furnished us by the U. S. Rubber Company labeled "Phygon Paste—55 percent dichloro naphthoquinone—'Micronized'" can be readily kept in suspension by use of an agitator in the storage tank. This material with its small particle size lends itself to the use of smaller nozzle orifices and thus provides a longer spraying period with better

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[2] Plant Pathologist, University of California, Davis, Calif.
[3] Agricultural Engineer, Spreckels Sugar Company.

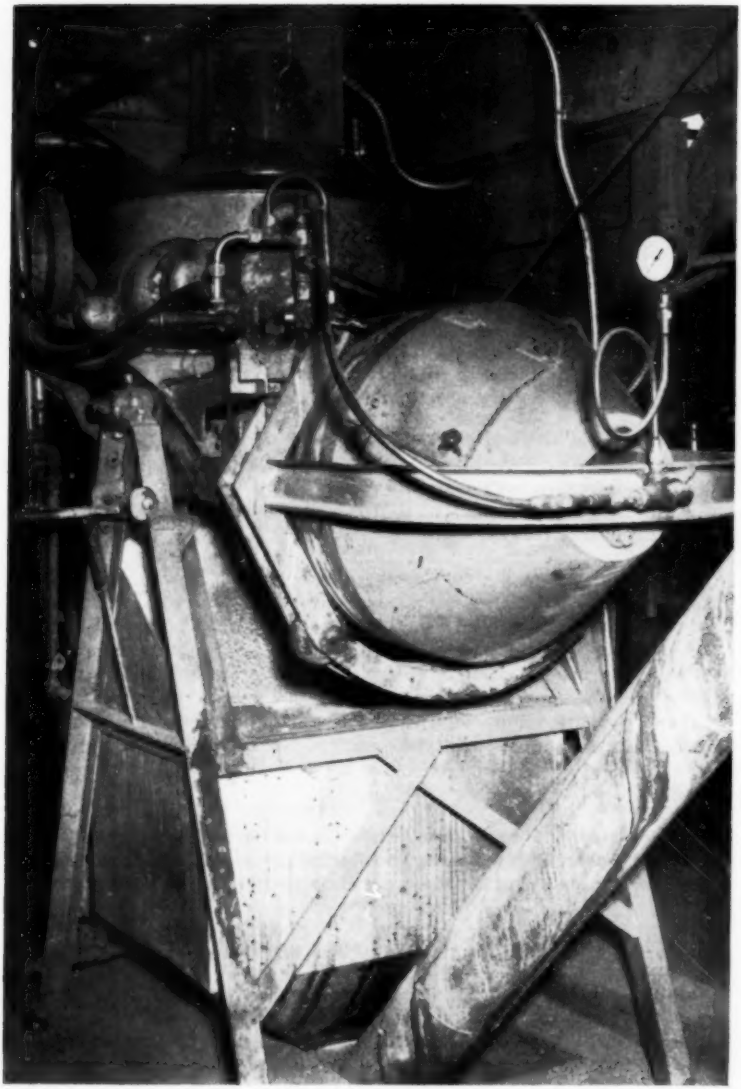

Figure 1. The Woodland spray treater after rebuilding. Changes included a conical end on the drum for better seed mixing and a 200 percent speed increase on the gear pump.

coverage. With the original Phygon Paste, the spray mixture contained 1 part Phygon Paste, 1 part beet molasses, and 2/3 part water. This material was applied at the rate of one quart to fifty pounds of seed. With the improved material the molasses has been eliminated entirely, and at present a mixture of 1 part Phygon Paste to 20 parts of water is applied at the same rate with very satisfactory results.

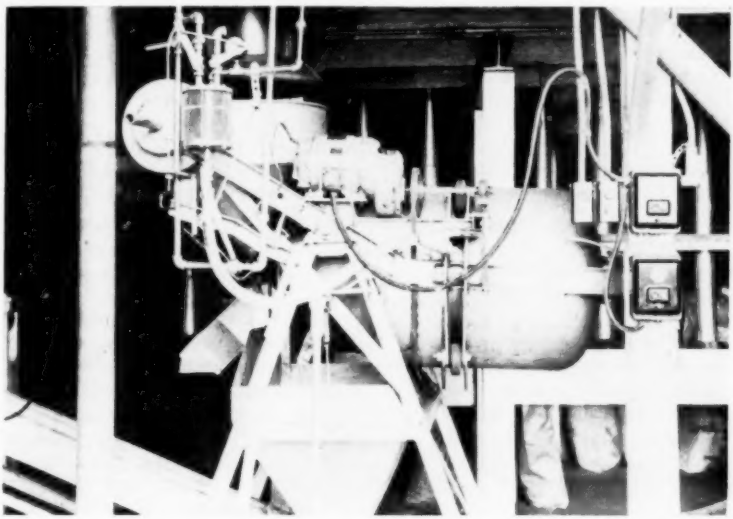

Figure 2. The Spreckels seed treater after rebuilding. Spraying pressure is obtained by admitting compressed air to the metering chamber for spray fluid.

Batch spray treating of beet seed has proved to be an indispensable addition to a seed processing plant. Some of the advantages are:

1. **Seed is furnished to growers ready to plant, dust-free, and properly treated with selected fungicides, insect repellents, or combinations of both.**
2. **The dust nuisance is eliminated in the processing warehouse and the operators are protected from toxic or skin irritating materials.**
3. **Accurate metering of both seed and treating materials can be accomplished by unskilled operators.**
4. **Seed returned by growers is acceptable for credit due to its good storage characteristics.**
5. **The batch method of treating synchronizes well with associated processing operations, and accommodates itself to a wide range of seed rates.**

Phygon Seed Protectant for Sugar Beets

T. W. BRASFIELD AND H. DOUGLAS TATE[1]

About ten years ago, research by Naugatuck Chemical, a division of United States Rubber Company, led to the discovery that 2,3-dichloro-1,4-napthoquinone, later assigned the trade name Phygon, was a potent fungicide. Since that time "Phygon" has been tested extensively by state and federal experiment stations and commercial organizations and proven to be a highly active fungicide having a wide range of effectiveness, both as a seed treatment and foliage spray. For a detailed discussion of the development of Phygon and related compounds as fungicides, the reader is referred to a recent paper by Schoene, et al, which appeared in *Agricultural Chemicals* (5)[2].

Phygon Improves Germination

"Phygon" has proven to be effective as a seed treatment on a variety of crops, including beets, sugar beets, corn, peas, spinach, Swiss chard, rice, alfalfa and others. It has proven to be particularly good on sugar beets as is shown by the following data:

Table 1.

Tratment	Dosage ozs./100-lb. seed	No. plants emerging from 100 seed units Greenhouse Cold Test	Field
Phygon	8	147.0	137.0
Phygon	4	70.0	132.5
Phygon	2	13.8	106.5
Check	—	14.0	59.5

In the foregoing greenhouse tests heavily inoculated soil was used and immediately after planting the seeds were placed in a cold chamber at 45° F. for seven days, thus producing a condition more severe than would be encountered in the field. It will be noted that in the greenhouse 8 ounces per 100 pounds of seed gave significantly higher germination than 4 ounces, whereas in the field 4 ounces per 100 pounds was adequate.

Phygon Prevents Post-Emergence Damping-off

Further tests showed that Phygon gave not only outstanding performance in improving germination, but also in preventing post-emergence damping-off which is of equally, if not greater, importance. This is illustrated by the following data on sugar beets:

[1] Naugatuck Chemical Division, United States Rubber Company, Naugatuck, Connecticut.
[2] Numbers in parentheses refer to literature cited.

Table 2.

Treatment	Dosage ozs./100 lb. seed	Greenhouse No. plants emerging from 100 seed units	No. Survivors
Phygon	8	167.0	130.3
Phygon	4	160.3	109.0
Phygon	2	163.8	104.8
Phygon	1	135.0	63.5
Check	—	88.0	33.5

Phygon Is Safe on Seed

From a practical standpoint, one of the chief requisites of an ideal seed treatment is that it be non-injurious to seed even when used in excess dosage and when the treated seed is to be in storage for a prolonged period.

There is convincing evidence that Phygon meets this requirement. In the 1948 report (3), "Cooperative Seed Treatment Tests on Sugar Beets," Dr. A. R. Downie, Chairman, Advisory Committee on Beet Seed Treatment, says: "The results obtained with Phygon are rather encouraging since we have been unable to demonstrate any injurious effects on germination even after the seed has been stored for three years." A storage test on sugar beet seed was started at Bethany, Connecticut, in 1945 and is continuing at the present time. The seed was treated at three dosage levels and stored in a constant temperature room at 50° F. Samples have been removed and germination determined along with an untreated sample stored under similar conditions at six month intervals. There is no evidence of injury as indicated by the following data, which cover a period of 18 months:

Table 3.

Treatment	Dosage ozs./100 lb. seed	Emergence from 100 seed units: Immediately after Treatment	6 Mos. after Treatment	18 Mos. after Treatment
Phygon	3.2	127.2	144.0	88.5
Phygon	1.6	84.0	145.3	48.8
Phygon	1.0	67.6	117.3	40.3
Check	—	38.8	76.6	28.8

Phygon Performance in Cooperative Tests

Phygon has been widely tested in recent years in the cooperative sugar beet seed treatment tests. In 1946 (2) tests were run in 36 different locations and Phygon was included in each. In the general summary of results, it is stated that Phygon, along with certain other treatments, "appear substantially better than the untreated checks." In 1948 (3) it was included in 22 locations scattered throughout the sugar beet growing areas and it gave significantly better stands than untreated seed in 11 of the 13 tests in which there were significant differences due to treatment. This was the highest rank attained by a non-mercurial treatment. The 1948 data pertaining to Phygon are summarized as follows:

Table 4.

	Untreated	Phygon
Average stand in 22 tests	36.10	49.32
Average stand in 13 tests which had Sig. Dif.	30.78	51.36

Two "Phygon" formulations are available and recommended for sugar beet seed treatment, viz., "Phygon Seed Protectant" for use as either dust or slurry and "Phygon Paste" for slurry or spray treatment.

Dust treatment continues to be an important method. Under some conditions, however, dusts are objectionable to the operator during treatment and to the grower during planting. As experience has demonstrated, these objections can be overcome to some extent by using the slurry method, but according to some workers this method, with the small amount of suspension ordinarily applied, does not provide uniform coverage due to the rough, corky, absorbent surface of sugar beet seed.

In early 1947 (1), Austin Armer, of Spreckels Sugar Company, suggested that Naugatuck Chemical consider development of a Phygon paste formulation which could be sprayed on to the seed, rather than dumped or poured as in the case of slurry, thus giving more uniform coverage. Working in close cooperation with Mr. Armer and Dr. L. D. Leach, of the California Agricultural Experiment Station, several formulations were prepared and physical and biological performance checked. Through this cooperation, a semi-fluid paste readily miscible with water to any desired consistency was developed. This formulation, now called "Phygon Paste," has proven to be satisfactory for both spray and slurry application not only on sugar beet seed, but also on other seeds.

The following information, taken from a report by Dr. Leach (4), gives a comparison of Phygon spray and dust treatment on sugar beet seed.

Table 5.

Treatment	Dosage ozs./100 lb. seed	Emergence from 100 seed units	Survivors from 100 seed units
Phygon (spray)	16	105.5	93.5
Phygon (dust)	16	105.5	92.0
Check	—	41.5	13.5

The safety and effectiveness of Phygon Seed Protectant and Phygon Paste on sheared sugar beet seed are demonstrated by the following data obtained in greenhouse tests at Bethany, Connecticut. It is of particular interest to note that no injury was caused by either of these formulations at 40 ounces per 100 pounds of seed:

Table 6.

Treatment	Dosage ozs./100 lb. seed	No. plants emerging from 100 seed units Trial 1	Trial 2	Trial 3
Phygon Paste	40.0	115.5	107.8	120.5
Phygon Paste	4.0	113.5	99.3	97.3
Phygon Paste	1.5	86.8	65.8	64.5
Phygon Seed Protectant	40.0	108.8	.....	.....
Phygon Seed Protectant	4.0	107.8	.....	.....
Phygon Seed Protectant	1.5	63.2	.....	.....
Check	.....	44.0	53.3	55.5

Phygon Sugar Beet Seed Treatment Recommendations

As is true with seed treatment in general, the optimum dosage on sugar beets varies with weather conditions and locality. For average conditions, Phygon seed treatment recommendations are as follows:

Phygon Seed Protectant — **4 ozs./100 lbs. seed**
Phygon Paste — **1 pt./600 lbs. seed**

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New Techniques in Seed Pelleting

PHELPS VOGELSANG[1]

Processed Seeds, Inc., of Midland, Michigan, is a comparatively new concern whose business is based on the commercial production of pelleted or coated seeds for general agricultural use. Our work is based on a number of years of intensive experimental work which was started in the early spring of 1942. The original experimental work was carried on under the auspices of the Dow Chemical Co., which made application for patents covering major phases of the process in February of 1944.

For a period of five years extensive research was required in order to determine coating materials, sticker solutions, etc., which were most suitable for incasing various seed types, and which would allow for the free absorption of soil moisture so as to give unhampered germination of the seed. The study also included the possible use of various ingredients such as fungicides, insecticides, fertilizers and stimulants which could be used in the process that would aid in protecting the seed from rot under abnormal conditions, protect the seedling from pre-emergence or post-emergence damping off diseases, protection in the early stages of growth from soil insects, and to stimulate the plant to vigorous growth.

Our greatest success has been along these lines and we consider earlier plant maturity and increased production with disease control to be of far more importance than the mechanical advantage of proper spacing. In the middle west spacing means little unless a high rate of emeregence can be assured.

In 1946 Processed Seeds, Inc., was organized and given a license by the patent holding company for exclusive use of the process and its development. Research has continued on a large scale under the new company, and already five additional patent applications have been made covering improvements in the process.

Research at the present time which is showing promise as reported by cooperators is classified as follows: Insect control in the early seedling stage through the incorporation of insecticides such as dithane, chlordane, methoxychlor, chloranil, lindane, calomel, bi-chloride of mercury and others. Success has been reported in work on cabbage and onion maggot, corn root worm, and wire worm on beans.

Fungicide studies are being made on some of the antibiotics such as actidione. These studies are in the preliminary stage, but show some promise because of the very low concentrations required and the ease of application. The incorporation of pure innoculant cultures on legume seed prior to coating and the lasting effects of such treatments in storage of the pellets is a major project.

The use of herbicide-resistant materials such as activated carbon when placed in a layer about the seed to protect it from injury of soil treatments with weed killers such as 2,4-D is of value. Such treatments have shown

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promise where soil temperatures are sufficiently high to insure complete dispersion of the herbicide before germination takes place.

In the pelleting of range grass seeds for aerial seeding in semi-arid regions it is essential that the seeds be coated with materials which will not disintegrate when in contact with moisture on the soil surface. If the pellet disintegrates so as to expose the bare seed the seed will not get sufficient moisture for a long enough period of time to germinate. It is therefore essential to make a pellet which will merely absorb sufficient moisture to cause germination through the coat. This feature alone has been the main reason for many failures in aerial seeding projects. A stable pellet is almost the opposite of our past pelleting technique and it has taken some careful study to develop a pellet of the required properties and still not retard germination. Pelleting of other seeds for aerial seeding is being studied carefully and next spring we plan some extensive field testing with spring wheat and spinach sown from the air.

For the past several years we have worked with cooperators in the study of surface seeding conifer seed pellets in reforestation. Very few of these trials have been successful to date. We have not been able to find a rodent repellent which is effective in protecting the seed from many rodent species. Conifer seed is slow to germinate so must be protected for long periods. Heavy poisons in the pellet are not desirable but appear to be the only method of protecting seed pellets in infested areas. Another difficult feature of this program is that the new seedling is very slow to establish a root system and if dry weather comes on while the seedling is very young it stands little chance to survive.

The seedlings also require partial shade and direct sunlight tends to dry them up before they take hold. Field conditions which are suitable and meet these requirements are very hard to find.

In the past our program has been handicapped in not having a planter available which would do an accurate job of space planting even though uniform and spherical pelleted seeds were to be had. Only recently a mechanical planter has been offered which affords adequate spacing. Our efforts in this direction have been in developing a planting unit which selects the pellets from the seed container by magnetism. The pellets are treated with a small amount of powdered magnetite and are picked up individually by magnets inserted in a wheel which passes up through the seed can. This action gives a minimum amount of abrasive action and breakage, as well as giving a zero momentum drop of the pellets in the planting furrow. Other advantages of the machine are simplicity of mechanism, low cost and ease of changing spacing on the ground. Also, adjustment will not be required when planting pellets of different sizes.

The use of pelleted sugar beet seed in the middle west has been increasing steadily. This increase has been a result of field performance and the request from growers for pelleted seed. This is the kind of growth we like to see and we prefer to have it come directly from the grower. In

Michigan, we still see a great deal of lack of uniformity in the planting of sugar beet pellets. Farmers plant all the way from 6 pounds of pellets per acre to 16 pounds. Where pellets are planted too thick the savings which could be effected both in seed and thinning labor are lost to some extent. We have inspected a great many fields and have noted that 7 or 8 pounds of pellets per acre give an adequate stand. The best field of beets I have ever seen in Michigan was planted with 6 pounds per acre. This is equivalent to 1 3/10 lbs. of bare decorticated seed.

In the middle west we are making a standard sugar beet pellet which contains 10% of the seed weight of regular arasan. This large amount of fungicide is required to give maximum emergence from the ground and to control seed rot under our usually wet and cold conditions. Fungicides to this extent are not required or recommended for use in warmer or dryer climates such as are encountered in the western areas. Under warmer conditions, which are more suitable to seed germination, 4 or 5% of arasan will give adequate protection. Faster emergence is also noted under these conditions. Arasan is the most expensive ingredient used in the pelleting process and an adjustment to meet actual needs will help to lower costs.

The Use of Coated Seed in Modern Agriculture

F. W. BURGESSER[1]

Any discussion of coated or pelleted seed should be prefaced by a paragraph on nomenclature. The term "coated seed" refers to a single seed coated with an inert material, primarily to increase its size to facilitate planting. Chemicals, such as pesticides and fertilizers, are sometimes added to the coating as it is applied to the seed. Coated seeds are mostly used in row crop farming for precision planting. Pelleted seeds are a mixture of seeds and an inert material formed into pellets, usually by molding by some mechanical means. The number of seeds in a pellet is not controlled accurately and any average number can be included, the average seed content depending upon the ratio of seed to pelleting material in the mixture from which the pellets are formed. Pelleted seeds are generally used in range land reseeding. The seed used is normally the forage grasses and some of the more hardy legumes. Fertilizers and seed protectants can be added if desired. Planting usually is done with an airplane. While this paper deals primarily with single-seed-coated seeds, pelleted seeds and their use will be mentioned later.

Since the development of a satisfactory coating material and the method of applying this coating material to an individual seed, the use of coated seed has become an accepted practice in the production of a number of row crops. The number of crops which can be benefited, either by reducing production costs and/or by improving the quality of the harvest, is being increased as research and experimentation continue.

The idea of coating seeds is quite old. A search of the Patent office files shows the first patent relating to seed coating was issued in 1868. Quite a number of patents have been granted since then. Nearly all of these patents have as their subject matter the coating of seeds with some fertilizer or other growth-promoting substance, and all used a binder of some sort to hold the coating material to the seed and to form a coated seed. Since the idea of precision planting is a comparatively recent introduction, nothing is mentioned in the older patents about increasing the size of the seed to facilitate planting.

The beet sugar industry was the initiator of the recent interest in seed coating. After the development of a successful method of breaking the beet seed ball into segments containing a high percentage of single germ seeds, the full advantage of the singleness of the processed seed could not be realized because of the fact that the planters available would not accurately space the seed in the row. As a means to obtain better spacing with the planters in use, the idea of increasing the size of the seed to approximate the size of the unprocessed seed was advanced. While the

[1] Agricultural Department, Filtrol Corporation.

coating work was in an experimental stage, precision planters were also being developed. Both developments became practical at about the same time.

The number of materials and mixtures of materials which was tried experimentally as seed coating materials runs into the hundreds. None of them was entirely satisfactory as long as a binder was required to make them adhere to the seed. Some of the experimental coated seeds gave fair results if they were planted immediately after coating, but after short storage periods the viability of the seed was affected. Further research showed that the binders used were for the most part responsible for the loss of viability. Experiments with various binders showed that if they were used in sufficient quantities and concentrations to produce a coated seed of sufficient mechanical strength to withstand passing through a planter, they also sealed the seed hermetically. Unless seeds are kept under ideal storage conditions they must respire, and the binder prevented respiration. Another objection to the binder is the length of time required for it to dissolve out of the coating and permit the soil moisture to contact the seed.

Research was directed toward finding a material which would adhere to the seed and form a coating without the use of a binder. The material should be porous to permit respiration, yet it should give the seed some protection against unfavorable atmospheric conditions during storage. It should not absorb moisture from the atmosphere but it should soften rapidly when in contact with moist soil and hold the moisture to the seed to promote germination. After considerable research and experimentation, a coating material meeting the above requirements and having additional attributes was developed. The most important of these additional attributes is the inherent fungicidal activity of the coating material.

After the demonstration of the successful use of the coating material on processed beet seed, farmers who grow other row crops became interested in the use of coated seed to reduce labor costs. One of the first of the row crop seeds other than sugar beet seed to be processed to coated seed was head lettuce seed. Other coated seeds used at present are: tomato, cabbage, broccoli, cauliflower, carrot, radish, onion — in fact, most of the annual vegetables and a large number of the annual flowers, both for cut flowers and for seed production. Inquiries are being received from growers of various other crops relative to the use of coated seed to reduce their growing costs, to save valuable seed or to protect seed during storage and planting.

The culture of head lettuce is quite similar to the culture of sugar beets in irrigated areas. Rows are spaced about the same—20 to 24 inches apart—and the plants need 12 to 14 inches in the row to develop properly. With the use of uncoated lettuce seed, a pound and one-half to three pounds of seed are used per acre. Each pound of lettuce seed contains an average of 400,000 units. Consequently, from 600,000 to more than a million seeds were planted to obtain a plant population of about 25,000 per acre. Lettuce seed is normally a high germinating seed, nearly all of it germinating well over 90%. The thinning operation was definitely a stoop labor, finger thinning job. The plants left to produce the crop were injured in that

their root systems were disturbed by having adjacent plants removed or by having part of their root systems exposed in removing unwanted plants. With coated seed, 3 to 4 ounces of original seed are used per acre and the seed spaced approximately two inches apart in the row. The thinning job becomes a long handled hoe operation and the expense was cut about 75%. The plants grew better since there was no seedling competition and plants were not subjected to any shock during thinning. Yields are increased and the percentage of premium heads is increased materially.

The coating of lettuce seed involved considerable difficulty in its development. Even now, after a vast amount of experience, it requires a much longer time to coat lettuce seed than is required for most other seeds. If a binder could be used successfully with this seed, a considerable amount of time would be saved. Lettuce seed is very sensitive to smothering and the coating must be porous to permit air movement during germination. The use of coated lettuce seed is becoming more popular as more vegetable growers learn of its advantages. The only hold-back to much wider use is the non-availability of suitable precision planters.

Tomato seed received early attention upon the request of farmers who were growing large acreages for canning factories. There was, at first, some doubt about being able to secure early enough harvest to compete with transplants from plant beds. Experience over the past several years has shown that direct seeding permits as early a first picking as is possible from transplanting in normal seasons. The direct field-seeded plants have a certain amount of frost resistance which is not apparent in the transplants. The saving involved in direct seeding amounts to the cost of the plants plus the transplanting costs, less the coated seed cost and the cost of planting. A direct-seeded field could be replanted repeatedly after frosts and the cost would not approach the cost of plants.

The tomato growers were, of course, primarily interested in the saving involved in using direct seeding in preference to transplanting. However, after the first season, this saving, as large as it was, became one of the minor advantages to the use of coated tomato seed. The spread of disease in the plant beds and by handling of the plants during transplanting was entirely eliminated. Very few tomato growers realized the toll taken by diseases which were spread in this manner. The direct seeded plants grew more upright and bushy, holding the fruit off the ground and permitting the harvest of a much higher percentage of first class tomatoes. Some expense was also saved in irrigation since the tap roots of the plants were allowed to develop normally, never being injured by removal from the plant bed or during the transplanting operation. Tomatoes are normally a deep-rooted plant, and when these tap roots were allowed to develop without interruption, they grew to a greater depth in the soil and showed less signs of wilting if irrgation was delayed.

During the 1948 season in the Sacramento area of California the spring weather was so wet and disagreeable that it was impossible to get into the fields until six weeks after the regular planting date. The tomato plants

in the plant beds were larger than was normally desired for transplanting but they were used in an effort to make up for the late transplanting date. Some direct seeding was done with coated seed at the same time the plants were set in the field. The transplanted fields did come into bearing about a week earlier than the direct-seeded fields but the direct-seeded fields out-yielded the others and continued to yield better fruit longer. The plants developed from the transplants were more or less prostrate in their growth and a large percentage of the tomatoes ripened on the ground and were subject to mildew and rot. The amount of disease in the transplanted fields was very pronounced. Nearly all the plants which were set out had been topped and the roots shortened. This topping and root amputation spread diseases among the plants and whole fields were infected with virus diseases.

It was thought that the shock of transplanting would delay the plants about a week or ten days. Actual experience has shown that it takes never less than two weeks, and sometimes as long as six weeks, for a plant to recover after being transplanted. Experiments were tried with the so-called "green wrap" tomatoes. These tomatoes are planted so that the fruit can be picked during the last part of September and October to be shipped to eastern markets after the eastern crop has been frosted. Normally, the plant beds for this crop are planted during the middle of April and the plants field-set during the latter part of May and early June. In the experiment, the plant beds were planted as usual and two weeks later the direct seeding was done. The direct-seeded tomatoes came into bearing four weeks ahead of the transplanted tomatoes and the first two pickings were sold to canners. The actual gain from the use of direct seeding was six weeks, showing that it took the transplanted plants six weeks to overcome the shock of transplanting.

The production of carrots from coated seed is another crop which is receiving considerable attention. Carrots are normally planted with what is commonly called a spread shoe. An effort is made to scatter the carrot seed in the band about 4½ inches wide. One band is placed on each side of a regular bed. Very poor distribution of the seed is obtained since the seed is quite light and it does not scatter well in the band. Some commercial carrot growers figured that if they could plant one carrot seed each inch or inch and one-half in the row, and have the rows spaced from one to two inches apart, their yield would be materially increased. Several large growers developed their own planters to handle coated seed in this manner. Their yields were increased at least 50% and the culls left on the fields were reduced by 85 to 90%.

The use of coated seed in the growing of onions is receiving considerable attention. Market gardeners who grow onions for bunching purposes want to plant in a manner similar to that used by the carrot growers. Growers of dried onions are obtaining better yields of more uniform-sized onions by accurate spacing of the seed in the row with the use of coated seed. In some areas, particularly the winter onion area, transplanting has been practiced. The cost under present day labor conditions amounts to about $30.00 per acre to have onions transplanted and the plant population after transplanting is seldom as large as desired.

Almost immediately after the seed coating idea was developed, the thought of adding various materials which might affect the germination of the seed or the vigor of the seedling was advanced. Experiments to date have failed to show a significant benefit to be derived from the use of the various plant foods or growth regulating chemicals. Most agronomists are of the opinion that the roots, as sent out from the seed, do not serve to nourish the plant until all of the plant food available in the seed has been used. Unless the coating material is unduly thick on the seed, any material incorporated in the coating will have no effect on the plants' growth. Neither food nor moisture is absorbed by the roots until the cotyledon appears above the ground.

The use of toxins, such as the fungicides and insecticides, does have a definite place in seed coating. It was established quite early that the seed coating developed to overcome the objections found with the use of a binder did have some fungicidal power inherent in itself. This coating material is 80% as effective as most fungicides. The amount of protection given by the coating alone would probably be sufficient to give a stand except under the most adverse conditions. However, in order to secure more definite protection and to meet the most adverse conditions, additional fungicides can be added to the coating without injury to the seed. Some of the metallic fungicides have proven toxic to the seed or seedling. The organic materials can be used in much larger dosage when combined with the coating than is recommended by the manufacturers for application to uncoated seed. The newer organic insecticides, such as DDT, BHC and Chlordane, have proved quite effective in the protection of the seed and seedling against soil insects and worms. These insecticides can be incorporated in the coating and experiments to date indicate that an adequate dosage has no adverse effect on the growth of the plant from the seed.

The general use of coated seed by the truck crop growers and market farmers is somewhat contingent on the development and widespread distribution of precision planters and weed control measures. Considerable advance has been made in the production of precision planters. Several planters on the market at the present time do a fair job. There is still room for a simple, inexpensive planter which can be used for planting coated seed and, with minor changes, for planting seed that is large enough not to require coating for precision planting. This field is being invaded by new firms and some of the new models look very promising.

When precision planters are generally available, potential users of coated seed will need to be instructed in planting techniques. It has definitely been shown that emergence is retarded by packing the soil over the seed. All agronomists agree that, in order for the seed to take up sufficient moisture to germinate properly, the soil must be held firmly around the seed. The present press wheels and methods of packing the soil around the seed are at fault since the pressure is applied on the top of the soil and very little is transferred to the area containing the seed, particularly if the planting is made at a depth of one inch or more. With the use of coated seed the packing becomes unnecessary providing the seed bed is firm. The coating material itself serves as the soil packed around the seed to conduct the moisture to

the seed. Coated seed plantings should be covered with loose soil. This permits ready emergence and the water-hungry coating pulls the moisture from the soil without having to be packed tightly. The furrow former, as developed by the Beet Sugar Development Foundation, is, in our opinion, one of the most noteworthy improvements in planting equipment to be developed in the last half century. With this type of furrow former the soil is compacted in the bottom of the furrow and, with the use of the proper method of covering the seed with loose soil, ideal emergence conditions are created.

The weed control problem is being given attention by the companies which supply chemicals to the agricultural industry. Several good herbicides are available but their proper application needs further study and experimentation. In the not too distant future, many of the row crops requiring considerable hand labor at present will be grown without any labor except for irrigation and pest control.

The idea of pelleting range seed to facilitate the reseeding of large areas has been under consideration for some time now and with some measure of success; however, not of the order even remotely suggesting a commercial product. This lack of success is due probably to the fact that it was thought initially that the idea involved merely the formation of a pelleted seed mass. More recent investigation has shown that on the contrary a number of factors are involved both as to the pelleting material to be employed and the manner of forming the pellet. Experiments embracing these more recent developments are now under way and it is expected shortly that it will be found that this entire problem will have been solved.

Beet Seed Standardization

R. J. TINGLEY[1]

The first practical method of reducing the number of sprouts per beet seed ball was the segmenting or shearing process developed by Professor Roy Bainer of the University of California College of Agriculture at Davis. The Holly Sugar Corporation recognized the possibilities of this new type of beet seed, and early in 1942 a single stone seed shearing unit was built and installed in the Holly warehouse in Stockton.

Because of the rapidly developing shortage of field labor and the demand on the part of the growers for some means of reducing labor requirements, sheared beet seed was accepted readily and the percentage of our total acreage planted with such seed increased very rapidly. The initial results under generally favorable field conditions proved satisfactory and the percentage of sheared seed increased further until 1945 and 1946 when about 90% of our plantings in California were made with this seed.

Because of the enthusiasm over this new development in beet seed and the critical need for field labor savings, some of the shortcomings and problems involved were not recognized immediately. Very soon, however, dry spring conditions and limited soil moisture produced unsatisfactory stands on a substantial portion of our total beet acreage.

The seed produced by this original shearing process was graded through 9/64ths and over 7/64ths round hole screens. While the resulting size was very uniform the seed pieces were still very irregular in shape, even though the process included a seed polisher. There were also a large number of exposed germs. Growers generally were very critical of these exposed germs and empty locules and were quick to criticize the whole principle of sheared seed planting when poor stands resulted from deep planting or limited soil moisture.

It was about this time that the importance of the damage done to the beet seed germ by the shearing process was generally recognized and Professor Bainer undertook further work in the perfection of seed processing to eliminate this fault and improve the recovery of good seed. As a result of this work, he developed the decorticating process which reduced the size of seed balls by the use of stone grinding wheels, stationary steel burr plates and rubber-faced pressure plates. It was immediately recognized that the seed produced with this process was improved insofar as damage to germs was concerned, even though the percentage of double and multiple sprouts was increased rather materially. Field tests showed that germination and emergence were improved significantly with this new decorticating process and the seriousness of higher double and multiple sprout count was recognized as being of minor importance.

The Holly Sugar Corporation worked with Professor Bainer and the Blackwelder Manufacturing Company to perfect a practical design for a commercial unit employing the principles worked out by Professor Bainer.

[1] Pacific Coast Manager, Holly Sugar Corporation.

With the use of this new type unit, the seed processed proved to be more symmetrical in shape and had fewer exposed germs, even though the seed size range of 7/64-9/64 was continued.

California beet growers readily recognized the improved features of this seed over the sheared product, and the grower demand increased rapidly through the 1947 and '48 crop years. During this time, the need for increased production necessitated the addition of two more University of California type decorticating units, as well as two new Eureka seed cleaners.

Early in the testing period of this expanded processing plant a fundamentally important factor was recognized. The gradual reduction in the size of the seed ball by successive grinding and polishing steps resulted in producing a much more desirable type of seed, of higher germination, and with a resulting higher recovery of the finished product than was possible with any single grinding action. This principle was utilized in a practical way by returning the over-run from the cleaners to separate decorticating units. In this way, the clearances between the stones and the steel and rubber wheels can be set to closer tolerances because of the uniformity of the seed introduced. We believe this principle has reduced the damage to seed, improved the germination and increased the actual recovery very materially. With the use of Eureka cleaners and some further grower acceptance of the increased germ count, it was decided to increase the seed size range to 7/64ths-9½/64ths and the resulting seed has been accepted very favorably by most of our growers.

Our beet growers generally have indicated their appreciation of our processed beet seed. The fact that it has been so universally satisfactory for all types of planting equipment and seed bed conditions has caused us to feel that this type and size of seed should become our standard product. While we have not had universal grower acceptance of this seed, the high percentage of our total acreage planted with it and the fact that the demand for graded whole seed is relatively unjustifiable, we hope to establish a policy beginning with the 1950 fall planting season of issuing only this standardized processed beet seed.

We believe that this type of seed can be planted in any and all planters now in use and at any desired rate, from the most limited precision spacing to the heaviest practical basis, where no thought of labor saving or mechanical thinning is planned. We have had such a universally satisfactory experience in securing good stands with this standardized processed seed, especially when treated with fungicidal and insect-repellent materials, that we feel there is little, if anything, to be gained by any change in size or methods of processing.

The following table indicates the approximate average specifications of our decorticated beet seed:

Screen hole size	7-9/64	7-9½/64
Bushel weight	30-31 lbs.	29-30 lbs.
Seeds per lb.	45,000-47,000	38,000-43,000
% Sprout count		
Singles	40-50	30-40
Doubles	25-40	40-50
Multiples	0-15	5-15
Hand Screen Fractions		
% of Sample on		
7/64ths	15-25	15-20
8/64ths	40-75	40-50
9/64ths	10-30	30-40
10/64ths	Neg.	0-5

We recognize some of the advantages of a definite standardization of processed beet seed to every one concerned, including the beet grower, sugar processing company and implement manufacturer. Certain economies in processing work can, no doubt, be effected and the product further improved by continued and more intensive work on our present processing methods.

We should be justified in arbitrarily issuing only standardized processed seed to growers, even including the old "die-hards" who still feel that they can produce larger beets from larger seed balls, or those who would like to utilize an old 1925 planter. The benefits of improved processed seed in quick germination, more uniform emergence and the increased vigor of seedlings should certainly justify the 100% acceptance and use of this seed.

We believe that some degree of standardization of processed beet seed among all sugar companies would be of material assistance in attaining further perfection, improving planting equipment and securing universal grower acceptance, and these advantages probably should determine the compromise which is necessary to bring about an ultimate standardized procedure.

Beet Seed Processing Problems at Rocky Ford, Colorado

C. W. DOXTATOR[1]

For the past five years all processed beet seed used in American Crystal Sugar Company factories east of California has been processed at the Rocky Ford, Colorado, seed processing plant. This plant is equipped with two decorticators and one segmenting machine, two seed cleaners and an automatic sacking out scale. All elevation of seed is by air suction, and dust from processing operations is settled in dust cyclones with the lightest fraction being drawn into a wet process disposal unit and exhausted as sludge.

During the past 3 years much attention has been given to the size of processed seed, with the object of obtaining 100 percent cell fill at the higher seeding rates (over 9 seeds per foot of row) in the presently used precision beet drills. As late as 1946 the size of processed beet seed was not a particular problem with the older drills and their "conversion units." During 1946 and 1947, the average seed size within the 7/64" to 10/64" size range was allowed to increase. This was accomplished by gradual reduction of the seed ball size in the processing operation. In 1947, 80 percent of the seed run over cleaners equipped with 7/64" and 10/64" round hole screens was found to be between 9 and 10/64" in size.

In 1947 some difficulty in obtaining adequate seeding rates per acre with precision drills was found, and many farmers enlarged cells in drill plates so that adequate seeding rates could be obtained. In 1947 experiments were conducted on seed sizes, and it was decided to use the Eureka No. 7 cleaner for the final cleaning, rather than on the 68 D Clipper, in order to reduce seed size slightly (1)[2], for 1948 seed issue.

1948 Experiments

Despite the average smaller seed size of 1948 issue seed, maximum cell fill was not obtained, particularly in the Red River valley of Minnesota and North Dakota, where the planting rate desired is 12 seeds per foot of beet row. During 1948, further experiments were conducted to determine all factors affecting cell fill in the seed plates. Processed seed of 7-8/64", 8-9/64", 9-10/64" and 10-11/64" sizes was sent to the Beet Sugar Development Foundation at Fort Collins, Colorado, for tests on the John Deere No. 66 and the International No. 40 drill units. Tests were made on the above four seed sizes and also on the following mixtures of sizes as follows:

	1947 issue
(1) 7-10/64"	
(2) 7-10/64"	(7-8:15%, 8-9:45%, 9-10:40%)
(3) 7- 9/64"	(7-8:25%, 8-9:75%)
(4) 9-11/64"	(9-10:50%, 10-11:50%)

[1] Plant Breeder, Beet Seed Operations, American Crystal Sugar Company, Rocky Ford, Colorado.

[2] Numbers in parentheses refer to literature cited.

Samples of processed seed of various mill runs of sizes 7-9/64", 7-10/64", and 9-11/64" were also sent to the American Crystal sugar factory at East Grand Forks where drill tests were made on these same drills. The results of these tests, aiming at 100 percent cell fill, were as follows:

(1) For light seeding rates, drill plate cells should be at least 1/64" larger in diameter than the largest size seed.

(2) For seeding rates of 10 to 12 seeds per foot of row, cell diameter should be 3/128" to 2/64" larger than the largest size seed.

(3) Worn drill plates can reduce cell fill by as much as 15 percent.

(4) John Deere drill plates having cells of .168" diameter, when drilled to 11/64" (.172"), planted as high as 23 percent more seed.

(5) All new plates should be checked for cell size and "smoothed" before use.

Since cells in drill plates in use in most eastern beet growing areas were .168" and .172" in diameter it was decided to reduce the seed size to 7-9/64" for 1949.

1949 Experiments

Early in 1949 units of 4 of the more commonly used beet drills were set up in the seed processing plant at Rocky Ford for testing daily mill runs of processed seed. Comparisons were made with new and worn plates, and also of cell sizes .168" and .172" for cell fill. The results substantiated the findings of the 1948 tests conducted by the Beet Sugar Development Foundation and the East Grand Forks factory of the Company.

Tests were also made, using 7-9/64" seed, of the effect on planting rate of different amounts of seed in the seed cans. In both the JD No. 66 and the International No. 40 drill units the seeding rate dropped as the amount of seed in the cans lowered. When the cans were kept ⅔ full, cell fill was computed to be 103 percent; at ½ full, cell fill had dropped to 98 percent, and when nearly empty, to 90 percent.

Cleaning Plant Changes

Both the Eureka No. 7 and the 68D Clipper seed cleaners are located on the second floor in the Rocky Ford seed processing plant. The Eureka No. 7, being equipped with a Buhler drive, absorbs the shake of the screen deck, but the 68D Clipper, having an eccentric drive, imparts great vibration to the entire building. To correct this condition a Buhler drive of the proper size, traveling the same rate as that on the Eureka, was installed on the Clipper in 1949.

This change eliminated vibration completely. However, the first seed processing tests with this modified cleaner showed a 20 percent lower plant capacity, as well as a smaller seed size than had previously been obtained. In Table 1 are given the results of seed sizing tests conducted with the two cleaners.

Table 1.—Effect of Buhler drive on sizing of processed beet seed on two seed cleaners.

Seed sizes[1] recovered	Percent recovery in rescreening from: Eureka No. 7 (with Buhler)	68D Clipper (eccentric shake)	68D Clipper (with Buhler)
Below 7/64"	.7	.9	1.0
7-9/64"	79.6	96.4	82.8
Above 9/64"	18.8	1.6	14.3
dust (by difference)	.9	1.1	1.9
Total	100.0	100.0	100.0

[1] Tests conducted on 1,000-pound lots of seed originally screened over the 68 D Clipper with eccentric drive in 1948.

In order to increase seed size from the modified Clipper to approximately the same as that produced by the Clipper in 1948, various changes were made. The stroke of the drive was reduced by one-half the length normally used, and the r.p.m. of the drive reduced from 514 to 411. These changes increased seed ball size to nearly that obtained from the eccentric shake as well as improving plant capacity. Further improvements in capacity were obtained by adjusting the pitch of both the 7 and 9 screens downward.

Summary

Processing of beet seed in the Rocky Ford plant has been greatly changed during the past four years. Seed size has been reduced every year since 1947 in an effort to obtain better cell fill in drills set for high seeding rates. Cells having at least 2/64" "clearance" over the largest sized seed appear necessary for adequate cell fill. Minor changes in seed cleaners have been found to affect greatly the average size of seed in the 7/64 to 9/64" processed seed size range.

Literature Cited

(1) DOXTATOR, C. W.
1948. Comparison of Clipper and Eureka cleaning mills on sizing of segmented beet seed. Proc. Am. Soc. Sug. Beet Tec., p. 125-28.

Experimental Studies Related to Seed Processing

H. L. BUSH[1]

Mechanization of the spring work related to the growing of the sugar beet crop can only be successful if small amounts of seed per acre are planted accurately. This seed should be composed of a lower number of germs than normal sugar beet seed, which may contain three or four germs in each seedball.

Until such time as the plant breeder is able to supply a variety of sugar beets having a mono- or bi-locular type of seedball, along with other desired characters, it will be necessary to process the seed in some manner in order to separate the original seedball into more than one portion, each containing one or two germs.

Considerable work has been done by the various sugar beet companies to arrive at a desirable method for processing the seed, with the result that many different types of processed seed are now being used.

Germination results for several lots and types of processed seed in comparison with unprocessed seed, as well as some bi-locular types, have been previously presented[2 3] as field results compared with laboratory results. These tests indicate an increase of about 12.8 percent in singles for field germinations over that obtained in the laboratory. Segmented seed gave about the same results as whole seed of the same graded size, while commercially decorticated seed resulted in a 10 percent lower potential germination under the same comparable conditions. However, one lot of bi-locular seed which was polished only lightly in the decorticator gave as good results as unpolished seed from the same lot.

MATERIALS AND METHODS

Polishing

To understand more fully the physical characteristics of sugar beet seed, three commercial lots of Great Western seed were polished and screened by hand. The hand polishing was accomplished by rubbing the seed between two pieces of heavy rubber until the first germ caps were observed to be loosened. Probably this would be considered as light polishing. Both before and after polishing, the seed was graded as to size, using a nest of hand screens. These screens were of the round-hole type with 1/64-inch difference in hole size between each screen.

Screening

Seed from five Great Western varieties of sugar beets, grown in several different years in Colorado, Arizona, Oregon, New Mexico and California,

[1] Statistician-Agronomist, The Great Western Sugar Company, Agricultural Experiment Station, Longmont, Colorado.

[2] Brewbaker, H. E., and H. L. Bush. Graded whole vs. segmented, pelleted, and single- and double-germ seed in field germination tests. Proc. A.S.S.B.T. Regional Meeting of Eastern Slope and Intermountain, 188-193, 1947.

[3] Bush, H. L. Field compared with blotter germinations for processed, graded, single- and double-germ seed. Proc. Amer. Soc. Sug. Beet Tech., 70-77, 1948.

were screened through the same nest of screens described above, in order to study the variation existing between different lots of seed from the same variety grown in different locations.

Field Germinations

In addition to the results previously reported[2,5], tests were made in 1949 in which various lots of processed and unprocessed seed were compared, using the same scheme of careful hand planting described in the previous reports, where two separate tests were conducted. One of these hand planted tests was composed of 3 replicates planted at four weekly intervals, during April and May, for a total of 12 replicates, in which case germinating conditions were rather poor; the other was composed of 6 replicates planted July 18, where irrigation water was applied so that rather high germinations resulted. In addition to the hand planted tests, one planting was made using an experimental plot planter, and another where a commercial drill was used, at Longmont, Colorado. Plantings were also made at Windsor, Colorado, where a commercial drill was used with two different rates of planting. The various lots of seed included in all, or part, of these tests are as follows:

1. Commercial segmented seed. In this, the 7-10/64-inch sizes were pre-screened and mixed with the segmented portions of the larger seed.
2. Decorticated seed. All of the whole seed of this lot was passed through the burr and polishing unit of the decorticator.
3. Decorticated mixture. This consisted of whole seed from the 7-10/64-inch size, seed from the 10-12/64-inch size which had been polished only in the decorticator, and decorticated seed from the plus 12/64-inch sizes of whole seed.
4. Decorticator-polished whole seed, prepared by working whole seed through the polishing unit of the decorticator until the largest segments passed through a 10/64-inch screen.
5. Forsberg-polished whole seed, prepared by processing seed with the Forsberg huller until it could be screened to the 7-10/64-inch size.
6. Unprocessed seed graded to 7-10/64-inch sizes.
7. Unprocessed seed graded to 10-12/64-inch sizes.
8. Ungraded whole seed.
9. Bi-locular strain, B401.
10. Mono-locular strain, B402.

RESULTS

Polishing

The results for polishing the three commercial lots of beet seed are presented in Table 1.

The original GW59-41 seed would be classed as small, while the GW85-42 and GW72-46 are medium and large, respectively. The fraction passing through the 6/64-inch screen is considered trash, and it is noted that a considerably higher percentage of trash is removed from the larger sizes of original seed than from the smaller sizes. The two large grades of seed (through 13/64 on 12/64 and through 12/64 on 11/64) reacted to polishing in a similar manner, regardless of whether or not the original lot was of

Table 1. Seed fractions, expressed in percentage, remaining on various screen sizes after hand polishing three commercial lots of sugar beet seed.

Grade Before Polishing	% Each (a Fraction Before Polish	Percentages for Each Fraction After Polishing						
		Thru 12/64 on 11/64	Thru 11/64 on 10/64	Thru 10/64 on 9/64	Thru 9/64 on 8/64	Thru 8/64 on 7/64	Thru 7/64 on 6/64	Thru 6/64
GW59-41 Colo.								
On 13/64 (b	14	.....	.....	.....	.....	.....	.....	.....
Thru 13/64 on 12/64	19	38.9	27.8	11.1	2.8	.....	.....	19.4
Thru 12/64 on 11/64	22	.....	46.6	33.3	9.5	0.2	.....	10.4
Thru 11/64 on 10/64	16	.....	0.3	42.1	36.8	10.5	.5	9.8
Thru 10/64 on 9/64	16	.....	.....	60.6	26.1	4.3	2.0	7.0
Thru 9/64 (b	13	.....	.....	.....	.....	.....	.....	.....
GW85-42 Colo.								
On 13/64 (b	32	.....	.....	.....	.....	.....	.....	.....
Thru 13/64 on 12/64	24	37.5	25.0	12.5	4.2	.....	.....	20.8
Thru 12/64 on 11/64	16	.....	40.9	36.4	9.1	0.5	.....	13.1
Thru 11/64 on 10/64	10	.....	5.9	64.7	11.8	5.9	.....	11.7
Thru 10/64 on 9/64	10	.....	.....	58.8	23.5	5.9	3.3	8.5
Thru 9/64 (b	8	.....	.....	.....	.....	.....	.....	.....
GW72-46 Colo.								
On 13/64 (b	53	.....	.....	.....	.....	.....	.....	.....
Thru 13/64 on 12/64	21	33.3	27.8	11.1	2.8	0.3	.....	24.7
Thru 12/64 on 11/64	10	.....	41.2	35.3	10.8	0.3	.....	12.4
Thru 11/64 on 10/64	8	.....	7.7	46.2	23.1	3.8	.....	11.6
Thru 10/64 on 9/64	5	.....	.....	33.3	54.6	5.6	1.0	5.5
Thru 9/64 (b	3	.....	.....	.....	.....	.....	.....	.....

(a Data from Seed Screening Test, 1948.
(b Not polished.

the small, medium or large size category, but for the smaller grades (through 11/64 on 10/64 and through 10/64 on 9/64) the variations due to polishing do not appear to be consistent with the original sizes of the three seed lots.

A considerably higher percentage of corky material was removed from the larger grades of original seed than from the smaller grades. Considering averages for the three varieties, at least 1/64-inch of corky material was removed by polishing from 10 percent of the large size seed graded "through 13/64 on 12/64" screen and 2/64-inch from 36.6 percent of the same grade; this in contrast with smaller seed graded "through 10/64 on 9/64" where 50.9 percent was not reduced as much as 1/64-inch in size by polishing.

Considering the three varieties used in this polishing test, it was found that, as an average, 11.3 percent of the unpolished seed graded "through 11/64 on 10/64" in the screening test. After polishing and re-screening, 4.6 percent of this portion, as an average for the three varieties, still remained on the 10/64-inch screen. This small fraction of polished seed accounted for only one-twentieth, or 5 percent, of the original seed lot. This might appear to be the logical division to consider as the largest size for graded seed which might be polished only, as compared with larger seed which would require some form of cracking to maintain a standard size of 7/64-10/64-inch for commercial seed.

Screening

The results for the screening test are presented in Table 2.

Table 2. Results for screening seed of several varieties grown in different locations in different years.

Variety	Where Produced	Year	Percentage of seed remaining on screens							% Thru
			13/64	12/64	11/64	10/64	9/64	8/64	7/64	7/64
GW59	Colorado	1941(a	14	19	22	16	16	10	2	1
GW59	Arizona	1944	13	18	25	19	18	6	1	..
GW59	Oregon	1944	10	15	26	20	17	10	1	1
GW59	Colorado	1944(a	28	26	16	12	12	5	1	..
GW59	Colorado	1945(a	16	18	20	15	15	12	3	1
GW59	Oregon	1945	12	18	24	18	17	9	1	1
GW59	California	1947	24	26	22	14	10	3	1	..
GW59	Oregon	1947	14	19	22	18	16	8	2	1
GW64	Colorado	1941(b	33	24	17	10	8	4	2	2
GW64	Oregon	1946	6	15	27	19	20	10	2	1
GW64	Arizona	1947	11	19	27	18	18	6	1	..
GW72	California	1946	32	28	15	10	8	4	2	1
GW72	Colorado	1946(a	53	21	10	8	5	2	1	..
GW85	Colorado	1942(b	32	24	16	10	10	6	1	1
GW85	Oregon	1945	12	17	26	18	18	8	1	..
GW85	Arizona	1947	10	23	26	18	16	6	1	..
GW201	Colorado	1944(b	50	19	14	8	5	3	1	..
GW201	Arizona	1946	24	23	22	15	11	4	1	..
GW201	New Mexico	1946	26	24	23	14	10	2	1	..
GW201	Oregon	1946	14	20	24	18	15	8	1	..
GW201	Arizona	1947	8	17	25	21	19	8	1	1

(a Grown by two-year steckling method.
(b Grown by overwintering method.

There appears to be a large variation, due to environment, in seed sizes between various lots of seed produced in different years at different locations for each of the varieties tested. Seed produced in Colorado or California tends to be larger than that produced in Oregon, Arizona, or New Mexico for each varietal comparison.

GW 59 appears generally to produce smaller seed with less variation in size than the other varieties, and GW72 might be classed as a large-seeded variety, based on the two comparisons for this variety. However, it is quite apparent that no definite prediction can be made relative to the seed size of any variety produced at any location.

Field Germinations

The results for the field germination tests, where each seed unit was carefully planted by hand, are presented in Table 3.

Table 3. Field germination tests. Percent singles, % germination and % potential seedlings as obtained in the field compared with results obtained on blotters for both 12- and 6-replicated tests.

			Blotter		Field					
			%	%	% Singles		% Germ.		% Potential	
Variety	Treatment	Size	Singles	Germ.	12 rep.	6 rep.	12 rep.	6 rep.	12 rep.	6 rep.
GW201	Segmented	7-10/64	46.2	94.8	66.9	53.4	37.7	63.7	32.9	67.2
GW201	Decorticated	7-10/64	36.1	93.5	63.4	50.4	39.1	59.2	33.9	63.3
GW201	Decort. Mixture	7-10/64	41.7	93.5	64.4	44.8	41.3	63.2	37.3	67.6
GW201	Decort. Polished	7-10/64	33.6	96.8	60.0	50.1	38.3	55.5	32.3	57.4
GW201	Forsberg Polished	7-10/64	23.2	90.5	60.7	46.0	30.7	45.7	23.8	50.5
GW201	No Processing	7-10/64	36.8	91.0	60.6	43.8	34.2	62.8	30.8	69.0
GW201	No Processing	10-12/64	16.2	97.3	53.1	29.0	39.3	70.0	29.0	72.0
GW201	No Processing	Ungraded	17.9	95.0	53.2	34.2	43.4	70.2	32.8	73.9
B401	Polished	Over 6	46.3	80.0	69.6	.....	32.7	.....	34.8	.....
B402	No Processing	Thru 6 slotted over 6 round	99.0	43.5	99.5	.....	14.6	.....	33.3	.....

The "Forsberg-polished" seed appears to have been injured somewhat in processing, since seed for this lot gave the poorest results, both in the field and on the blotters. The "Decorticator-polished" lot gave some reduction in % potential in the 6 replicated test; otherwise, none of the processed lots, except the "Forsberg-polished," show any consistent or definite indication of having been injured in processing, as no essential difference in % potential is indicated for any of these other lots.

The inherent possibilities with regard to single-germness are indicated by the results obtained from the mono and bi-locular strains (B402 and B401), where 99.5 and 69.6 percent singles, respectively, were obtained in the field.

The results for the tests planted with the various drills are presented in Table 4.

Table 4. Field potential germination, expressed in percentage, for various lots of processed and unprocessed seed.

		Longmont		Windsor	
		Exp.(a	Comm.(b	Commercial Drill	
Treatment	Size	Drill	Drill	2+ lbs./A	4+ lbs./A
Segmented	7-10/64	63.2	53.7	60.8	66.0
Decorticated	7-10/64	65.4	44.2	59.3	63.9
Decorticated Mix.	7-10/64	68.1	51.1	58.4	62.1
Decorticator Polished	7-10/64	52.9	43.5	57.8	58.1
Forsberg Polished	7-10/64	50.7	39.0	54.0	52.6
No Processing	7-10/64	.....	46.0	.....	.....
No Processing	Ungraded	65.7	.....	.....	.....

(a Planted at rate of 12 germinating units per foot of row.
(b Average rate of planting—5.99 pounds per acre.

The "Decorticator-polished" and "Forsberg-polished" seed gave comparatively low percentages of potential in the Longmont plantings, but only the "Forsberg-polished" seed appeared inferior at Windsor. Also, com-

pared with unprocessed seed, there is some indication that these two products suffered some injury due to processing. Other comparative differences are small, and since there are fluctuations in the results between the different tests, in all probability there was not a real difference between the segmented, decorticated or "Decorticated mix" lots.

SUMMARY AND CONCLUSIONS

1. Polishing studies indicated that whole seed which graded 10/64-inch in size, or smaller, might need only a light polishing to prepare it for commercial use, while larger seed must be cracked in some manner if the commercial product is to be graded to a 7-10/64-inch size.

2. Large variations were found in sizes between various lots of seed produced in different years at different locations for each of several varieties tested.

3. Segmented and decorticated seed produced, essentially, the same percentage of potential seedlings when planted in the field. Polished seed resulting from processing in the Forsberg Huller appeared to be of inferior quality compared with segmented or decorticated seed.

Moisture Content and Germination of Sugar Beet Seed

F. H. PETO[1]

The 1948 beet seed crop in the Fraser Delta of British Columbia was harvested under abnormally wet conditions. Occasional light showers delayed the swathing somewhat, but the combining was stopped completely for 10 days by several heavy rains. In some cases the underside of the swath failed to dry out completely before combining was necessary. Consequently, the average moisture content in some of the freshly combined seed was very high. This very wet seed was dried in the country within a few hours after combining, to reduce the moisture to between 15 and 17 per cent. It was then shipped to the cleaning plant and redried either before or after cleaning to about 12 per cent or less.

The equipment used to dry the crops both in the field and at the factory was a portable "American All-Crop Dryer." This unit consisted of two 3- or 5-gallon oil burners and a propeller-type fan driven by a 5 HP motor and capable of delivering 20,00 C.F.M. at ½ S.P. The hot air from the fan entered the drier box through a 36-inch diameter canvas duct. The drier box was mounted on a standard four-wheel farm wagon.

The outside dimensions of the drier box were 17x8x4 feet. The beet seed in 100-pound jute sacks was laid in two layers on a heavy screen supported about one foot above the bottom of the box. The bottom layer of sacks were laid on their sides in one direction with narrow spaces between the sacks to permit hot air to strike the second layer which was laid tightly packed in the opposite direction. The temperature of the air on entering the seed was 100° F., but a great deal of this heat was extracted by the damp seed. This type of drier was found to be very economical of fuel, since the drying is accomplished with a small amount of heat and a large amount of air. Only one 3-gallon burner was used to maintain the desired air temperature, but if more rapid drying were necessary it might be possible to use somewhat higher drying temperatures without damage to germination. Accurate information on the upper temperature limit of safe drying of beet seed was not available. The drying box had a capacity of 2 tons and the moisture content was reduced by about 2 per cent per hour.

One-pound samples of the undried and dried seed from the final drying at the cleaning plant were sealed in cans and stored for 13 months at room temperature. They were then retested for moisture content and germinability and the results are shown in Table 1. All of the analyses were done at the Plant Products Laboratories of the Dominion Department of Agriculture in Vancouver, which have co-operated generously in these tests.

Where the seed had been dried to an average moisture content of 10.7 per cent, the germinability improved slightly during the storage period from 79.9 to 83.3 per cent. The undried seed with a moisture content of 14.9 per cent deteriorated badly in storage and germinated only 50.9 per cent when retested.

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The relation of moisture content to germination after 13 months storage is illustrated in Fig. 1, which shows that the viability of the seed declines sharply in storage at moisture contents above 12-13 per cent.

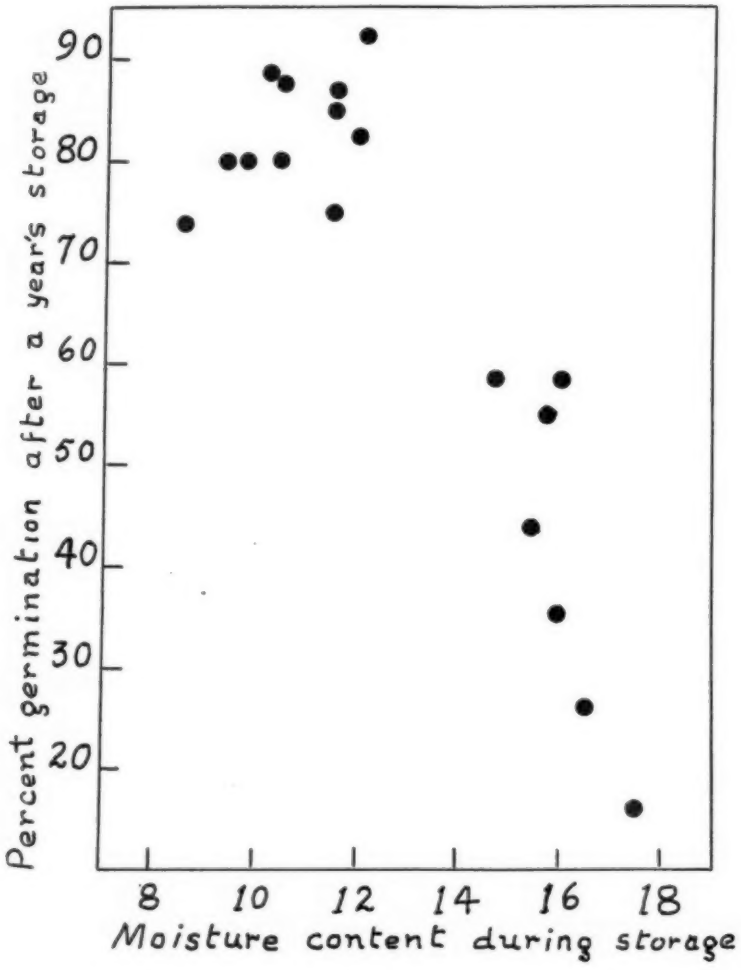

Figure 1.

In actual practice, the sugar beet seed is shipped to the prairies as soon as possible after harvest and if it contains excess moisture will usually dry out gradually in transit and storage. In spite of this, we believe that seed should not be shipped or stored with the moisture content in excess of 13 per cent.

Table 1—The Effect of Drying on Germination

Grower	Percent Germination of fresh seed	Tests run after 13 months storage					
		Undried		Dried		Difference	
		% moisture	% germ.	% moisture	% germ.	% moisture	% germ.
Ellis	78	16.3	26	9.9	80	—6.4	+54
Freisen	75	14.8	59	11.6	85	—3.2	+26
Guichon	86	10.2	89	9.4	80	—0.8	—09
Honeyman	91	15.8	55	12.2	93	—3.6	+38
McCubbin	78	16.0	58	11.6	87	—4.4	+29
Neilson	75	16.0	36	10.6	88	—4.5	+52
Reifel	80	15.7	44	10.5	80	—5.2	+36
Savage	81	17.4	16	8.7	74	—8.7	+58
Trim	75	11.5	75	12.0	83	+0.5	+08
Averages	79.9	14.9	50.9	10.7	83.3	—4.2	+32.4

Sulphuric Acid Scarification of Seedballs of Beta Trigyna and Other Beta Spp.

DEWEY STEWART[1]

Seeds of *Beta trigyna* Waldst. & Kit. and related species of the section *Corollinae*, as well as seeds of the three species in the section *Procumbentes* of the genus *Beta*, usually fail to germinate under conditions favorable for the germination of sugar beets. In greenhouse plantings of these hard-seeded species a few seedlings may emerge over a period of several weeks but the total germination of a seed lot is seldom as high as 20 percent. If the relatively thick, hard layer of tissue surrounding the seed is cut away, germination will occur immediately even in freshly harvested seed. It has been found that the hard tissue can be removed sufficiently to permit prompt germination by the corrosive action of sulphuric acid without serious injury to the embryos.

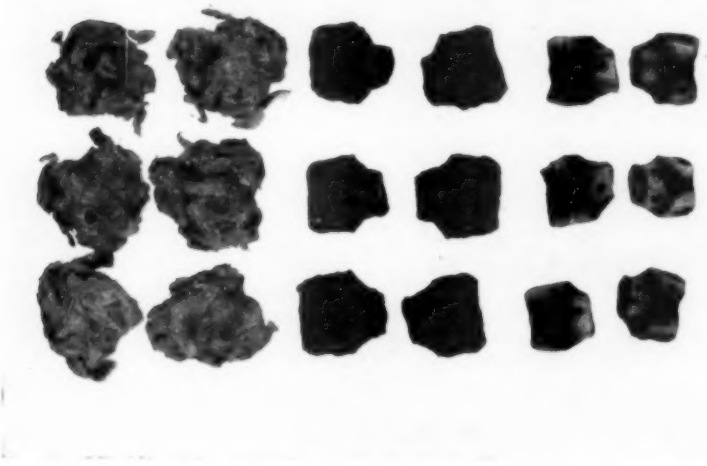

Figure 1. Seedballs of *Beta trigyna:* On left, untreated; Center, 3 hours in H_2SO_4; Right, from sample shown in Center given 2 additional hours in H_2SO_4, or a total of 5 hours.

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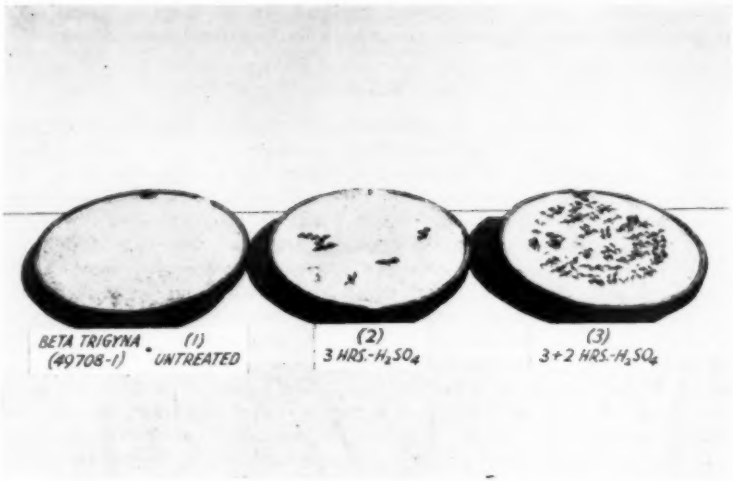

Figure 2. *Beta trigyna*, seed lot 49708-1. Left, untreated, germination zero; Center, 3 hours in H_2SO_4, germination 15 percent; Right, from same sample as shown in Center but given 2 additional hours in H_2SO_4, germination 92 percent. Fifty seedballs planted in each dish.

Methods

Concentrated sulphuric acid (sp. gr. 1.84) is added to the seeds slightly in excess of the amount they will take up with stirring. The length of time the hard seeds must be exposed to the action of the acid for effective scarification is not the same for all species and, furthermore, the small seeds of a sample require a shorter period than the larger ones. Seeds of the monogerm species *B. procumbens* Chr. Sm., *B. patellaris* Moq., *B. webbiana* Moq., and *B. lomatogona* Fisch. & Mey., as well as the small seedballs of *B. trigyna*, show a marked increase in germination after a treatment of two hours. The larger seedballs of *B. trigyna* require an additional treatment of two or possibly three hours, making a total of 4 or 5 hours in the acid, as shown in Figure 1. Although the above schedule of treatments has been used, it must be recognized that a satisfactory scarification depends upon the extent to which the hard tissue has been decomposed by the acid and this can be determined only by examination. A treatment which produces the type of sculpturing shown in Figure 1, right, in 20-30 percent of the seedballs has given the highest germination with the least injury to the seedlings. Drastic treatments to expose all the seeds or to free them completely from the mother tissue will result in severe injury or possibly the decomposition of the seed itself. The development of temperatures above 60° C. in the seeds during treatment should be avoided and as an aid in this respect a container, relatively large in comparison to the quantity of seed being treated, has been used.

After the seeds have been scarified, they are transferred to a large volume of water, washed through a screen and finally rubbed in a fold of

cheesecloth to remove the charred material. It has been a practice to transfer the seeds to dilute lime water for a few minutes before drying.

Results

The hard-seeded species of *Beta* frequently produce seeds of poor quality. Often the seed coats are empty or contain a seed not fully formed and nonviable. A germination of 50 percent following scarification has been considered good since this is thought to approach the true viability percentage of the seeds. When one considers the fact that within a period of two weeks after planting the untreated seeds usually germinate less than 1 percent, the value given for scarified seeds represents a marked improvement. Occasionally plants have been found which produce seed of high quality as shown for a plant of *B. trigyna* in Figure 2. This seed lot, 49708-1, also gave a striking demonstration of the improvement in germination which may be obtained from sulphuric acid scarification. A planting of 100 seedballs, 50 per dish, did not give a single seedling during a period of three weeks, as shown for the dish on the left in Figure 2. Sulphuric acid treatment for 3 hours gave one or more seedlings from 15 percent of the seedballs planted; an additional treatment of 2 hours, making a total of 5, gave the remarkable germination of 92 percent.

Although ample plants have been obtained from plantings of the hard-seeds to maintain the species in culture, it can be said that the low germination of the seedballs of *B. trigyna* and *B. lomatogona* has discouraged or made impractical extensive tests to evaluate them under field conditions. Scarification has given seed lots satisfactory for this purpose.

Sulphuric acid scarification is a practice of long standing for hard seeds, especially species of legumes and grasses, but this is thought to be the first report of its application to obtain germination of hard-walled fruits of *Beta*. Seedballs of the sugar beet and those of its cultivated relatives germinate promptly when planted under favorable conditions, therefore sulphuric acid scarification has no place in the processing of commercial beet seed.

Plant Improvement and Seed Production

Further Studies on the Inheritance of Black Root Resistance in Sugar Beets[1]

H. W. BOCKSTAHLER, G. J. HOGABOAM, AND C. L. SCHNEIDER[2]

In the humid areas of the United States and Canada, production of sugar beets is threatened by a disease commonly known as black root. The pathogen, *Aphanomyces cochlioides* Drechsler, is capable of invading all parts of the root system. Laggard plant growth, caused by persistent attack of the pathogen on the small feeder roots, and rot of the main root, which may result in the death of the plant, are the chief manifestations of the disease. Seedling stands are frequently reduced, but this phase of the disease is subject to control to a large extent by seed treatment or other means. Outbreaks of black root in fields in which the plants are past the thinning stage have not been prevented effectively by direct control measures. Strains of sugar beets capable of making vigorous growth under such black root exposure, and giving a plant population at harvest not greatly reduced from that left at thinning, have been found (2, 5)[3]. Progress reports of breeding programs give promise of the development by breeding of resistant varieties for use in areas in which black root is serious (1, 3, 4).

Henderson and Bockstahler (6) reported results with hybrids as compared with their inbred parents which indicated dominance of the black root resistance character. However, the hybrid populations as grown by them contained an undetermined percentage of plants of the maternal line.

To study further the mode of inheritance of the black root resistance character, plantings of sugar beet hybrids and their parental lines were made in 1949 in soil naturally infested with *A. cochlioides* at Waseca, Minnesota, East Lansing and Blissfield, Michigan. Many of the parental lines had been tested previously and the disease reaction of these was known. In most of the hybrid populations the F_1 plants could be identified in the seedling stage by hypocotyl color or in the larger plants by bud color. The performance of two hybrids and their parental lines is selected for tabulation as giving the most decisive results. The results of the tests as a whole are given as general statements of performance.

Materials and Methods

Single-row plots 20 feet long were used in all tests. The parental lines and hybrid were planted in adjacent plots. Two of these parent-hybrid-parent groups were planted at each of the three locations. A susceptible variety was planted at regular intervals to serve as an indicator of the uniformity of disease exposure.

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[1] Cooperative investigations of the Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, and the Michigan and Minnesota Agricultural Experiment Stations.

[2] Pathologist, Assistant Agronomist, and Assistant Pathologist, respectively, U. S. Department of Agriculture.

[3] Numbers in parentheses refer to literature cited.

All seed lots were treated with Arasan to reduce seedling losses. Estimates of seedling stands were taken before thinning. Spacing of approximately 12 inches in the row was used. In hybridizations involving inbreds of unlike bud color, the seedling populations were thinned to give a complete stand of F_1 plants so far as possible. In some plots of hybrids it was necessary to leave plants unidentified as to hybridity if a uniform spacing was to be maintained. Harvest data included number of roots and weight of roots for each plot.

Experimental Results

Line A, used as the pollen parent in hybrids J x A and B x A of Table 1, in homozygous dominant for the factors determining pink bud color, and the maternal Lines B and J are of the recessive genotype. Thus, in these two crosses all F_1 plants can be identified in the progeny of B or J. From previous tests Lines A and J had been classed as black root susceptible, and Line B resistant. Their performances in these tests were in agreement with the previous classification. It should be mentioned that the hybrids used in these tests were known to give satisfactory yields in absence of black root. The inbreds A and J had been considered valuable as breeding material before their reaction to black root was observed.

Hybrid J x A produced by the mating of two susceptible lines gave performances as to mean root yield and stand at harvest not strikingly unlike that of the susceptible check SP 1-9-00. When the susceptible Line A was mated with resistant Line B, the hybrid gave a performance strikingly unlike that of J x A. The hybrid B x A gave a higher mean root weight than either parent and a gain of 46% over that of the susceptible check. The plants in 100 feet of row at harvest showed a higher survival in the hybrid over that of the susceptible lines and their hybrid. The difference in performance of the hybrids J x A and B x A in which the susceptible Line A occurs as the pollen parent is attributed to the resistant character in Line B. In these hybrids, the black root resistance in Line B is transmitted to the hybrid as a dominant character.

For the entire planting of many hybrids and parental lines at the three locations, a covariance analysis of the data for emergence stands and final stands failed to show that the emergence stand had any effect upon the final stand. This indicates that factors other than seedling diseases operated to reduce the stand between emergence and harvest.

When the strains in this experiment were grouped according to type of reaction, the mean plot yields of the four classes were as follows: (1) Susceptible parents 9.61 pounds; (2) susceptible x susceptible hybrids 9.60 pounds; (3) resistant x susceptible hybrids 14.13 pounds; and (4) resistant parents 13.76 pounds. Upon applying the "t"-test, it was found that the probability that the resistant x susceptible hybrid will yield the same as the resistant parent exceeds the 50 percent point. The probability that the resistant x susceptible hybrid will yield as low as the susceptible parent is less than 1 percent. This test also showed that the probabilities that the susceptible and resistant parents would yield the same are less than 2 percent. In the susceptible classes the average yields of the parents and the hybrids were so nearly identical no "t"-test was required.

Discussion

From the results of this experiment it appears that in a resistant x susceptible cross the reaction of the resistant parents is transferred to the hybrid since the yield of the hybrid equals or is better than that of the resistant parent and, in nearly all cases, is significantly better than that of the susceptible parent. Similar trends were observed in the tests in 1945 in Minnesota (6). Any hybrid vigor that might be expected when susceptible inbreds were crossed apparently was nullified by the disease effects. Variability between plots with respect to incidence of black root proved a disturbing factor in the tests. Large plant populations, together with more replicates at each location, are needed to increase precision. Increase of plot length and selection of test areas with more uniform infestation with the pathogen may be effective in this regard. The resistance of many of the parent strains included in the experiment traces to variety US 216, which is only moderately resistant to black root. As inbreds are produced which show greater resistance to the disease, or vice versa, inbreds with greater susceptibility, we may expect more outstanding contrasts between the various classes of hybrids, and the effect of the dominant factors for resistance will be more pronounced.

Table 1.—Comparisons of sugar beet hybrids with their respective parental lines in tests at Waseca, Minnesota, Blissfield and East Lansing, Michigan, under black root exposure.

Current S.P. Numbers	Description	Mean Root Weight[1] Pounds	as % Check	Stand[2]
1-9-00	Susceptible Check	0.7,000	100.0	61
451043-0	Line J (susceptible)	0.5,652	80.7	66
451805-02	J x A (susc. x susc.)[3]	0.7,500	107.1	74
461001-0	Line A (susceptible)	0.7,634	109.1	71
46116-01 (MS)	Line B (resistant)	0.9,036	129.1	83
471807-02	B x A (res. x susc.)[3]	1.0,218	146.0	87
461001-0	Line A (susceptible)	0.6,627	94.7	67

[1] Calculated from total weight of all roots at harvest in 5 single-row plots 20 feet long.
[2] Total plants harvested from 5 single-row plots 20 feet long.
[3] Identified F_1 plants in Hybrid J x A and Hybrid B x A were 87.5 and 97.5 per cent, respectively. In these crosses the F_1 plants can be identified by bud color since Lines B and J are of genotype rr and Line A is homozygous for the dominant allele.

Summary

Inbred strains of sugar beets, classified as either susceptible or resistant to black root, and hybrids between them were planted in naturally infested soil in Michigan and Minnesota in 1949.

In average root yield per plot susceptible x susceptible hybrids were not significantly different from their parents. Resistant x susceptible hybrids yielded as much as, and usually more than, the resistant parents and significantly more than the susceptible parents.

The hybridization of a resistant line and a susceptible one gave a hybrid with the disease reaction of the resistant parents. The hybridization of susceptible lines gave a susceptible hybrid.

The conclusions reached in previous work that resistance to black root is transmitted to the hybrid as a dominant is confirmed in these tests.

Analysis of variance for average root yield per plot failed to show significance for the differences between the susceptible x susceptible hybrids and their parents. On the other hand, comparisons between hybrids and parents of the resistant x susceptible cross showed that all hybrids outyielded their susceptible parent, although in some cases the differences approached but did not reach significance.

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Breeding for Resistance to Root Rot Caused by Sclerotium rolfsii

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Southern root rot caused by *Sclerotium rolfsii Sacc.* is found in beet growing areas of the Sacramento River in California and in some areas of western Texas. In California very great loss has been experienced on many fields.

Present control measures are (a) the indexing of the soil to ascertain the number of *sclerotia* of the fungus present, (2)[2] for the purpose of determining whether beets can be grown safely, and (b) heavy nitrogen fertilization of those fields where the fungus is present (3).

Breeding for resistance to the southern root rot was begun in 1946 at Clarksburg, Calif., by the Beet Seed department of the American Crystal Sugar company. The progress of this project is summarized in this paper.

Experimental Procedure

During the 1946 season plans were made to select surviving beets of the American 5 variety in areas where beets were dying of the disease. Fifty good beets were obtained in very severely infested areas, all of which could be considered as escaping the disease either because of resistance or because of lack of the organism where these particular beets were growing. These roots were placed in cool storage until November when they were replanted at Placerville, Calif., for production of seed. In 1947 a similar procedure was used and 167 beets obtained from the American 5 variety.

Harvest of seed from individual beets in these selections was planned for mother progeny tests in replicated plots, similar to the procedure used in Aphanomyces root rot resistance breeding (1).

Experimental Results

Almost complete failure was experienced in the 1946 selection, since, of the 50 beets planted for seed, only four showed any life during the following spring, and only one of these produced seed. A few roots were obtained from seed of this plant in 1947 at Rocky Ford, Colo. A seed increase was obtained in 1948 and a large root selection made in 1949 for a bulk seed increase (and individual plant seed lots) in 1950.

From the 167 beets selected in 1947 and replanted for seed production 90 plants produced seed in 1948. The 10 highest seed yielding plants were harvested separately. A bulk seed lot of 14.2 pounds, representing the best of the 80 remaining flowering plants, was also obtained under the breeders' stock number 8-204.

In 1949 a field known to be severely infested with *Sclerotium rolfsii* was selected for tests of individual plant lines and of the bulk increase obtained the previous year. Seven plant lines along with the American 5 parent were planted in five replications of two-row plots 25 feet long, adjacent to which

[1] Research assistant and plant breeder, American Crystal Sugar Company, Clarksburg, California, and Rocky Ford, Colorado, respectively.

[2] Numbers in parentheses refer to literature cited.

were planted four strips each of the bulk increase 8-204 and of the American 5 percent. Because of the severity of the disease, a very great loss of beets resulted after thinning, and those which remained were of small size at harvest. All of the best beets in all plots were selected for seed increase purposes, in an effort immediately to improve any resistance which may have been previously obtained.

The performance of the selections as compared with the check variety was determined first by notes on vigor of growth after thinning, and later on the tenacity of the beets to live until harvest. These results are given in Tables 1 and 2.

Table 1.—Performance of 7 mother progenies selected for southern root rot resistance, along with parent variety; Clarksburg, Calif., 1949.

	Emergence data		
M-line Number	Seedling vigor[1]	Total beets per 100′ of row	Percent Survival at harvest
8-204-1	2.8	73	50
8-204-2	4.8	47	53
8-204-3	3.8	64	56
8-204-4	6.6	33	62
8-204-5	4.8	64	51
8-204-6	5.4	52	48
8-204-7	3.8	70	54
Significant difference	4.0	62	38
odds 19:1	2.5		13.0

[1] 1 = vigorous 8 = weak

Table 2.—At harvest survival of breeders' stock 8-204 as compared to the parent variety in a 4 replicate strip test. Clarksburg, Calif. 1949.

	Percent survival at harvest	
Replicate	8-204	Amer. 5
1	39.3	24.0
2	71.4	43.9
3	61.5	45.0
4	70.6	47.6
Average	60.7	40.1

The results of the mother line test, Table 1, indicate significant differences in both vigor of seedling growth and percentage survival at harvest. Survival at harvest of the 7 M-lines ranges from 48 to 62 percent for an average of 53.4 percent as compared to 38 percent for the check variety. There is no indication that seedling vigor was associated with percentage survival at harvest.

In Table 2 the survival of the breeders' stock 8-204 is higher than the check variety in all four replications. Differences between these two varieties range from 15.3 to 27.5 percent.

Conclusions

The results of these two replicated tests indicate differences in percentage survival between individual mother lines, between mother lines and the check variety, and between the mass selection 8-204 and the check variety under severe root rot conditions. Differences between the resistance selections and the parent variety are similar in both tests. It is extremely unlikely that

this result could have occurred in both tests due to chance. As a result of these findings breeding for resistance to this disease is being expanded considerably in 1950.

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1948-1949 Progress in Breeding Sugar Beets for Resistance to Aphanomyces Root Rot

C. W. DOXTATOR, A. R. DOWNIE, J. F. SWINK, D. OGDEN, R. L. BOWMAN AND J. C. TANNER[1]

During the past two years breeding sugar beets for resistance to *Aphanomyces cochloides* (Drechs) has been expanded to include the Red River valley in Minnesota and North Dakota, and areas in northwestern Montana. In general the experimental work was conducted along the same lines as in previous years (1), (2)[2].

This paper reports the progress made in developing resistance in adapted varieties for these areas, as well as the results from newer selections in the northern Iowa-southern Minnesota area.

MATERIALS AND METHODS

The selections tested in 1948 and 1949 at Mason City, Ia., and Waseca, Minn., were obtained from previous selections of the variety American 1, which variety has been the source of all resistance to this disease obtained by the American Crystal Sugar company in this area up to the present date. In the Red River valley, hybrids of American 3 Northern and American 1 resistant types were used for tests in 1948. Nineteen forty-nine tests in this area were from selections of the varieties American 3 Northern and American 3 Leaf Spot Resistant. At Missoula, Mont., in 1949 test plantings were made of individual plant seed lots obtained from U. S. 33, made the previous year. Further, since the test fields used in the Red River valley and northwestern Montana had only one year's record of root rot conditions, duplicate plantings of certain selections from the American 3 varieties and U. S. 33 were made at Mason City as insurance that reselections under disease conditions would be made in 1949. All seed lots tested in both years in the breeding nurseries of Montana, Minnesota and Iowa were individual plant progenies derived from open pollinated mother beets planted in the greenhousees at Rocky Ford, Colo. Selections of roots from the three above mentioned areas were shipped to Rocky Ford in time for winter seed production in both years. Check varieties used were U. S. 216, American 3 LSR, and the very susceptible variety S.P. 1-9-00, furnished by the U. S. Department of Agriculture.

In both 1948 and 1949 99 plant progenies of American 1 resistant were tested in 4 replications of plots. The 1948 test at East Grand Forks was of 33 plant lines in unreplicated plots and the 1949 test was of 55 plant lines in duplicate plantings. The Missoula test in 1949 was of 48 plant lines in 3 replications of plots. Plots in all nursery tests were 1 row wide by 20 feet

[1] Plant breeder and plant pathologist, respectively at Rocky Ford, Colo.; and research assistants at Rocky Ford, Colo., Mason City, Ia., Chaska, Minn., and East Grand Forks, Minn., respectively.

[2] The numbers in parentheses refer to literature cited.

long. In addition to these tests, inbred seed lots and hybrids were planted at Mason City and at Rocky Ford in 1948, and at Waseca and Rocky Ford in 1949. All nursery plantings were used for selection of mother beets in 1948 and 1949.

Three replicated plot tests for yield were continued in 1949, one at Mason City, Ia., and two at Moorhead, Minn. The Mason City test was made up of 9 breeders' stocks of root rot resistant origin in six replications of plots 3 rows wide by 40 feet long. One Moorhead test was of 11 mother progenies of American 3 Resistant along with 5 check varieties in 6 replications of plots 1 row wide by 50 feet long. The second Moorhead test was of 3 varieties in six replications of plots 1 row wide by 20 feet long.

EXPERIMENTAL RESULTS

1948 Selections

In 1948 root rot conditions at Waseca were not as severe as in previous years, and less severe than at Mason City. Leaf spot appeared in the Mason City nursery and selections were made for resistance to this disease as well as for root rot resistance. Average stand counts and vigor notes for the 99 lines and the 3 check varieties compared with the lines selected are given in Table 1.

Table 1.—Average stands per 20 feet of row, and vigor indices for 99 lines and 3 check varieties compared with lines selected. Mason City, Ia., and Waseca, Minn., 1948.

	Ave. Stand	Vigor Index[1]
	Mason City	
99 lines	11.7	3.32
3 check varieties	4.2	3.32
26 selected lines	11.8	2.94
	Waseca	
99 lines	11.26	2.91
3 check varieties	7.52	4.41
26 selected lines	13.05	2.92

[1] 1 = vigorous; 5 = weak.

The best roots of all of the 26 Mason City lines were planted in the Rocky Ford greenhouses in late December for winter seed production, along with the best roots of 16 of the 25 lines selected at Waseca. These selections were placed in separate houses. In a third house, root selections made at Moorhead, Minn., and at Missoula, Mont., from American 3 and U.S. 33 respectively were planted. All plants were inbred, using one Kraft bag per plant; and crosses were made between beets from the Waseca selection of American 1 RR, and American 3 and U. S. 33. At harvest, open pollinated seed was harvested separately from all plants, the best seed lots being used for 1949 nursery plantings.

1949 Selections

Root rot conditions in the Mason City and Waseca areas in 1949 were the reverse of those prevailing in 1948. The extremely severe conditions prevailing at Waseca eliminated most of the stand in all 99 lines and checks. At harvest all beets in this test were harvested by line, after which only the best beets from the best lines were saved.

On the basis of percent stand and vigor notes taken as in the previous years, 15 lines at Mason City were judged to be superior to others, and 245 beets were selected out of these lines. At Waseca some 65 lines were used for selections, with only 12.2 percent of the beets in these lines being selected.

Line selections of beets were also made in remnants of the 6 replicate M-line test and the 55-line nursery test at Moorhead and the 48-line nursery test at Missoula. The best of these root selections, along with those from Mason City and Waseca, were shipped to Rocky Ford for greenhouse seed production in the 1949-50 winter season.

1949 Yield Results

In Table 3 are given the results obtained from the breeders' stock variety test conducted at Mason City in 1949.

Table 3.—Root rot resistance variety tests, Mason City, Ia., 1949

Variety	Description	Tons Beets per Acre	Percent Sucrose	Lbs. Sugar per Acre	Vigor Index[1]
8-706-X	1947 Amer. 1 RR Sel.	12.87	13.63	3,516	2.4
1949 GH	GH O.P. Amer. 1	13.32	13.13	3,491	2.0
7-609-X	1946 Amer. 1 RR Sel.	12.88	13.35	3,448	2.5
Amer. 3 LSR	Com'l check	11.98	12.85	3,090	3.0
8-413	12 line Sel. MC '47	11.85	13.03	3,079	3.5
6-423-X	1st inc. Amer. 1 RR	11.03	13.18	2,936	3.5
7-606	1st Sel. 1945	11.25	12.87	2,908	4.1
8-705	M-line from 7-606	9.92	13.35	2,671	4.0
8-804	1st Sel., Amer. 3 N	8.88	11.50	2,036	4.2
Significant Difference (odds 19:1)		1.91	.95	547	
F Value		4.65[2]	3.29[2]	5.91[2]	

[1] 1 = vigorous; 5 = weak
[2] Significant beyond the 1% point

During the growing season foliage was most vigorous on the American 1 resistant varieties, the order of rank being as follows: 1949 greenhouse OP (49 increase), 8-706-X (1948 increase), 7-609-X (1947 increase) and 6-423-X (1946 increase). The latest increase, 1949 greenhouse OP, was significantly higher in yield than the first root resistant increase, 6-423-X. Eight-eight

Table 4.—Results of mother line test, Moorhead, Minn., 1949

Variety	Description	Tons Beets per Acre	% Sucrose	Lbs. Sugar per Acre
7-609-X	Amer. 1 RR, '48 inc. check	6.09	22.51	2,732
M 19	8-804-9	6.32	21.62	2,727
23	-26	6.05	21.68	2,613
16	-3	5.81	22.03	2,564
26	-38	5.99	21.20	2,518
24	-33	5.58	22.02	2,461
25	-34	5.15	22.01	2,260
21	-16	4.87	21.49	2,062
6-423-X	Amer. 1 RR, '46 inc. check	4.15	22.65	1,876
Amer. 3 LSR	Commercial check	4.10	22.89	1,865
M 18	8-804-7	4.10	22.60	1,842
22	-24	4.14	21.96	1,819
26	-10	4.18	21.63	1,812
Amer. 3 N	Commercial check	3.43	22.53	1,536
M 17	8-804-5	2.79	22.00	1,229
S.P. 1-9-00	USDA Susceptible	2.44	22.17	1,082
General Mean		4.70	22.06	2,062
Significant Difference (19:1)		1.59	.78	683

hundred four, a first selection for resistance made in the East Grand Forks area, was lowest in yield, indicating that very little resistance had been obtained from that selection.

In Table 4 are given the yields obtained from the 6 replicate M-line test conducted at Moorhead, Minn., in 1949.

Due to a severe late season drought, yields of all varieties were low. However, highly significant differences between varieties were obtained for tonnage yield and pounds sugar per acre. 7-609-X, the 1947 American 1 RR Breeders Stock, was significantly higher in tonnage yield than the other 4 checks, 6-423-X, American 3 LSR, American 3 N and S.P. 1-9-00. Lowest in yield was S.P. 1-9-00, the USDA susceptible check.

For a further check on the performance of American 3 LSR, variety commercially used in the Moorhead area, all 6 plots of each of the 3 check varieties in the 55-line Moorhead root rot resistance nursery were harvested. The results of this comparison are given in Table 5.

Table 5.—Yields of root rot resistant variety checks in the 55-Line Moorhead test of 1949.

Variety	Tons Beets per Acre	% Sucrose	Lbs. Sugar per Acre
S.P. 1-9-00	2.16	19.57	842
Amer. 3 LSR	5.49	19.14	2,126
Waseca RR '49 (Amer. 1 RR)	14.01	19.35	5,289
General Mean	7.22	19.35	2,776
F value	39.51[1]	.82	39.35[1]
Significant Diff. (19:1)	2.75	.67	1,050

[1] Exceeds 99:1 odds (8.65)

Striking differences were found for yield in this comparison, with significant differences being obtained between the 3 varieties. Where *Aphanomyces* root rot occurs in the Red River valley beet growing area, it is evident that a variety as resistant as American 1 RR is needed.

SUMMARY

During the past two years selection for beets resistant to *Aphanomyces* root rot has been expanded to include the Red River valley beet growing area of Minnesota and North Dakota, and the Missoula, Mont., area.

Selections for these new areas, made in the two types of American 3, and in U. S. 33, although showing some resistance, are not resistant enough to withstand severe attacks of the disease. Hybrids of these selections, with highly resistant American 1 selections, are now being made.

A test conducted at Mason City in 1949 of elite stocks from selections made each year since 1946 showed that the 1949 selection under medium severe root rot conditions was significantly higher in yield than the 1946 (first) selection.

Under severe root rot conditions in the Red River valley, seed obtained from roots selected in American 1 RR at Waseca in 1948 yielded 14.01 tons beets per acre compared with a yield of 5.49 tons per acre for the commercial variety American 3 LSR.

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Cold Resistance in Sugar Beets

R. R. WOOD, H. E. BREWBAKER, AND H. L. BUSH[1]

The use of controlled low temperatures as a means of selection is not new to plant breeders; it is relatively new, however, in its application to the sugar beet.

In 1931 the junior writers[2], working in the U. S. Department of Agriculture at Fort Collins, Colorado, using outside temperatures during the winter months, found very striking differences in cold resistance between individual plants within a variety and also between inbred lines. (See Figure 1.)

Portable Refrigeration Equipment

Two alternates are available when one considers the manipulation and physical problem of handling plant material to be subjected to low temperature exposure: (a) the plants can be transported from their place of growth to a permanently constructed low temperature chamber, and (b) portable equipment may be devised which can be transported to the plants where they are growing. The writers chose the latter method as being more versatile and probably somewhat more adapted to the requirements to be met in working with the sugar beet crop. The portable type described below is more economical of construction than the permanent chamber; and while this particular model would not be adapted for use with a mature corn plant, it would be usable for treatment of all kinds of plants in the seedling stage and many kinds of plants in mature stages.

The refrigeration unit employed uses a ½ horsepower electric motor, air condenser, single phase compressor with seven-foot air gravity type cooling coils inside the refrigerator box. Power required is 110-volt alternating current; this requirement is met in the field by use of a portable gasoline-operated generator. About the only innovation from a standard refrigeration design is the introduction of a solenoid valve into the liquid coolant line between compressor and regular expansion valve. This additional valve is controlled by a remote bulb-type thermostat, the bulb of the thermostat being placed in a central location within the box. By means of this additional valve and thermostat combination we are able to control the temperature within a much narrower range than would otherwise be possible if we were to depend solely upon the expansion valve regulator. Temperatures are controllable within ± 3 degrees Fahrenheit at any temperature down to 0 degrees Fahrenheit. The rated capacity is in excess of 3,500 B.T.U. per hour with an outside temperature of 80° F. and box temperature 20° F. Insulation of the box consists of a three-inch layer of Fiberglas with a one-half inch layer of Celotex.

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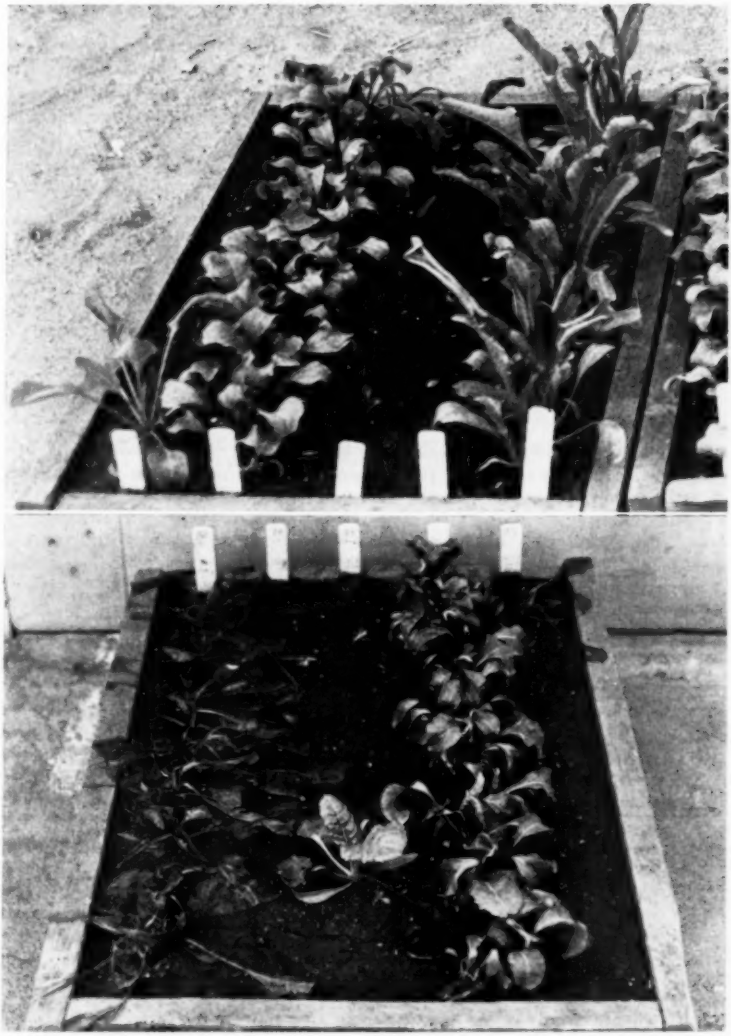

Figure 1. A (above). Seedlings in a flat before exposure to freezing temperature. B (below). Seedlings shown in A after freezing. Position of flat is the reverse of that shown in A.
(Experiments at Fort Collins by H. E. Brewbaker and H. L. Bush in 1931.)
Photo by U.S.D.A.

It is essential to have some movement of air within the box, otherwise local temperature fluctuations will occur. This is accomplished by use of an ordinary small squirrel-cage type of electric blower of 120 cubic feet per minute capacity. The introduction into the box of the small amount of heat from the fan motor is apparently advantageous in that it serves as a buffer to the more violent temperature fluctuation which would otherwise occur when the solenoid valve opens abruptly to admit refrigerant to the cooling coils. The rate at which temperature within the box can be reduced is dependent upon several factors: mass of material in the box, kind of material upon which the box rests (wet or dry soil, boards, cement or other), each of which have a different rate of heat exchange, etc. Access to the box is gained by hoisting one end, material in flats or other containers is placed in position underneath, and the box is lowered. In the field the box is simply lowered over the material to be frozen. Inspection of material during freezing is limited to one port approximately 7 inches square. A port is also provided for insertion of instrument bulbs, fan cords, etc., and has a reasonably tight-closing rubber gasket.

Transportation in the field is accomplished by raising one end at a time and putting thereon an axle and wheels; by use of such a wheel arrangement and a small chain hoist jack, movement of the machine is accomplished rapidly and easily.

With the above equipment it is possible, on dry soil and with a normal load of eight flats, to reduce the temperature from 80° F. to 0° F in less than 4 hours and maintain it at that level. With flats precooled in the hardening room the desired low temperature is attained easily in 1 hour or less. For seedling studies, the clear space inside the refrigerator box, without the collar, will accommodate eight greenhouse flats at a time, the usual size of greenhouse flats being about 15 by 20 inches. From our limited experience it appears to be important to hold down the plant population within the flat, thereby enhancing air circulation around each plant and preventing the formation of local areas in which the bunching of plants provides some protection to those within the clump. For studies of mature beet plants having much larger leaves, a "collar" or wall, insulated in the same manner as the box, will first be placed around the plants, then the refrigerator box placed thereon; the collar thus prevents mechanical injury to any of the leaves by raising the refrigerator unit above them.

Cold Resistance and Sucrose Content

Surviving plants from overwinter plantings at Windsor and Keenesburg, Colo., where winter killing was in excess of 99 percent, were grown to seed in 1937. Progeny testing from this selection was begun in 1940. One additional selection at Windsor on the basis of winter survival, and selection at Sterling under leafspot *(Cercospora beticola)* exposure, was given this material. It became evident in variety tests conducted in the years 1940 to 1943 that sugar content for the resulting selections GW201 and GW72 had been improved when compared with the parental variety GW25, the yielding ability remaining unchanged.

In order to obtain a comparative performance of GW25 with the two selections, GW201 and its sister line GW72, over a longer period, it is necessary to compare through a standard variety since the parent was discontinued in test after 1943. For this purpose, the long-time standard GW18 was chosen and a comparison of its sugar content and yield with that of GW25 over a three-year period is given in Table 1.

Table 1.—Comparison of Variety GW25 with Standard GW18, Longmont, Colo., Scottsbluff, Nebr., and Lovell, Wyo.—1939, 1940, and 1943.

Variety	1943			1940	1939	
	Longmont	Scottsbluff	Lovell	Longmont	Longmont	Mean
Tons Beets per Acre						
GW25	18.04	20.55	17.67	26.26	18.04	20.11
GW18	17.93	21.67	17.88	25.82	17.53	20.17
LSD 5% pt.	1.31	1.97	1.90	.56	1.11	.66
% Sugar						
GW25	16.18	13.85	17.63	11.94	14.84	14.89
GW18	16.45	13.90	17.33	12.15	14.74	14.91
LSD 5% pt.	.50	.67	.70	.34	.62	.26

With such a close record of performance over a three-state area, it appears quite certain that GW18 is essentially equivalent in performance to GW25. The comparison of sugar content of varieties GW201 and GW72 with standard GW18 is given as the result of 20 varietal evaluation tests over the seven-year period 1940-46, inclusive, and represents data from beet-growing areas in Montana, Wyoming, Colorado, and Nebraska under widely diverse environmental conditions. The data are presented in Table 2.

Table 2.—Comparison of percent sucrose of GW72 and GW201 with GW18 (Standard)

Variety	1940	1941	1942	1943	1944	1945	1946
GW72			14.84	16.89	17.43	15.73	14.25
GW18			14.26	16.31	16.74	15.09	13.83
LSD 5% pt.			.31	.28	.36	.27	.34
GW201	14.48	15.27	14.18	15.58	17.24	15.45	14.31
GW18	13.88	14.79	13.72	15.06	16.73	15.09	13.83
LSD 5% pt.	.12	.29	.35	.35	.36	.27	.34

The increase in sugar content in GW201 and GW72 over GW18 is equally apparent at high levels of fertility and production as at average or low levels; likewise does this hold true for high and low levels of sugar content. It has long been recognized that beets growing at higher altitudes and in more northerly latitudes are generally richer in sugar. Notable in the evidence given in Table 2 was the fact that at Hysham, Mont., and Lovell, Wyo., where higher sugar content is customary, the superiority in sugar content of GW72 over GW18 is still significant.

While the evidence for increased sugar content in GW201 and GW72 as a result of mere selection for winter hardiness is rather convincing, there is some contradiction in a similar mass selection made from GW59. Some 80 non-injured stecklings were transplanted in the spring of 1943 from a fall-planted field of this variety. C233, which resulted from a direct increase of this selection, showed no improvement in either yield or sugar content as compared with the original variety. Results are presented in Table 3.

Table 3.—Comparison of Variety C233 with Parent GW59

	Tons Beets		Percent Sugar	
	Longmont	Ft. Morgan	Longmont	Ft. Morgan
C233	21.69	26.82	12.13	13.13
GW59	21.49	27.46	12.42	13.09
LSD 5% pt.			.89	.95

The experience of Lund[3] in Denmark corroborates the evidence given above for GW201 and GW72. The possibility of employing cold resistance as a means of obtaining an increased sugar content without loss of yield would, however, appear to have definite limitations, or at least require further demonstration, as indicated by the results obtained with GW59.

Selection for Cold Resistance

The survival of a few plants under conditions of severe winter injury indicates selection for cold resistance within varieties. Lund[4] found considerable variation between plants in cold resistance in the material with which he was working; however, his principal objective is to increase cold resistance in order to reduce winter killing in overwinter planting for seed. He reports some survival, after proper conditioning, down to temperatures of 12 degrees to 14 degrees Fahrenheit. In northern Colorado and elsewhere it is known that plantings for production of seed by the overwinter method may survive outside temperatures considerably below zero with very moderate losses.

The possibilities for selection were explored in a cooperative study at the University of Wyoming at Laramie in March, 1949, using low temperature equipment located at that institution. Twelve varieties with 3 replicates each, hardened off with a series of cold shocks and subjected to a temperature of approximately 12 to 14° F., showed a variation in percentage killed over a range of 43 percent to 72 percent of the total population. This preliminary work helped materially in the development of techniques necessary to the proper use of low temperatures for selection work.

Frost Resistance in Mature Beets

No actual data from planned experiments on frost resistance of mature beets is yet available; however, a sudden drop in temperature in the fall of 1948 was sufficient to show differences in varietal reaction in variety tests planted at Fort Morgan, Colo., and Gering, Nebr. This drop in temperature at Fort Morgan was to a low of 24° F. on October 7 followed by 5 days of minimum temperatures ranging from 25° to 31° F. At Gering the minimum temperature on October 10 was 26° F.; on October 11, 19° F.; and again on October 12, 19° F. In both cases there was very little possibility of hardening off. Categorical ratings of foliage injury on a basis of 0 = none to 10 = destroyed were made at each of the above locations. The averages of these readings on 9 replicates of each of 36 varieties at Gering ranged from 2.9 for variety B389 to 7.9 for variety GW64; at Fort Morgan from 3.3 for variety C381 to 7.0 for variety GW159. In general the varieties showed a very similar

[3] Lund, Viggo. Private communication.
[4] See footnote 3.

reaction to frost at each of the two locations. The correlation coefficient (*r*) between percent sugar and frost injury at Fort Morgan was —.79 and at Gering it was —.80, both values being highly significant.

Inasmuch as many of the varieties in the above two tests had a previous history of selection for resistance to leafspot *(Cercospora beticola)* it is pertinent to compare the reaction to leafspot with reaction to frost. Categorical ratings of leafspot were taken as 0 = none to 10 = destroyed. Where these leafspot readings were correlated with those of frost injury, the *r* value at Fort Morgan was .77 and when leafspot at Fort Morgan was correlated with frost injury at Gering (no leafspot encountered at Gering), the *r* value was .59, both values very significant. In both tests there was evidence of adequate variation within most varieties to permit good selection for cold resistance in mature plants. The period just prior to harvest is generally the period of most rapid accumulation of sugar, and continued effective metabolism at this stage is extremely profitable.

Germination of Beet Seed at Low Temperatures

Resistance to frost injury in the seedling stage poses the question of how early seed might be planted in the spring with the expectation of getting safe germination and emergence. Preliminary studies of 16 varieties germinated at temperatures of 35 degrees to 37 degrees gave germination percentages from .7 percent to as much as 38 percent, demonstrating that there exist rather broad differences between varieties with respect to ability to germinate at low temperatures.

Summary

Preliminary evidence has been accumulated which indicates that (a) sufficient genetic variability exists between and within lines of sugar beets to permit selection for the character of cold resistance in both seedling and mature plants; (b) results presented are suggestive of sufficient genetic relationship between frost resistance and sugar content to enable one to make improvement for both characters by selection for cold resistance alone; and (c) differences exist between varieties with respect to ability of their seed to germinate at low temperatures.

Effects of Freezing of Sugar Beets Being Overwintered in the Field For Seed Production in Western Oregon[1]

RAY A. PENDLETON[2]

Introduction

Normal winter temperatures in western Oregon are nearly ideal for producing complete thermal induction for seed stalk formation in early fall planted sugar beets which are left over winter in the field. Temperatures seldom drop below 20° F. and the average for the three winter months of December, January, and February is usually around 40 to 45° F. Beets planted during the period from early July to early September usually survive such temperatures with very little loss from freezing. However, seed yields in the Willamette valley have frequently been below expectations. This may be due in part to the small size of roots of the seed plants. In this area where temperatures are very favorable for thermal induction roots of the beets usually do not develop further after growth is resumed in early spring. Subsequent growth is associated only with seed stalk formation. Another possible cause of low seed yields is the rather heavy defoliation of plants which usually takes place during the late bloom stage. Causes of the defoliation are not well known.

The winter of 1948-49 was exceptional in that the mean monthly temperature for December was 1° below normal, for January it was 9° below normal and 1° below in February. The mean minimum temperatures for these three months showed a wider divergence with, respectively, 4°, 11°, and 2° below normal. For nearly a month the temperature remained below freezing, and minimum temperatures of around 5° F. were reported for several locations in the seed growing area. Figure 1 shows comparative temperatures of the 1948-49 winter season and the normal for the Corvallis Station. As a result of the prolonged cold many beets had badly frozen crowns.

Literature Review

Evidence has been presented by Owen et al. (3)[3] to show that a prolonged temperature exposure of around 40° F. is optimum for thermal induction of flowering in sugar beet plants under low photoperiod conditions. Either warmer or colder temperatures are less effective. Pentleton (4) found that beet plants which have been partially reverted to vegetative condition

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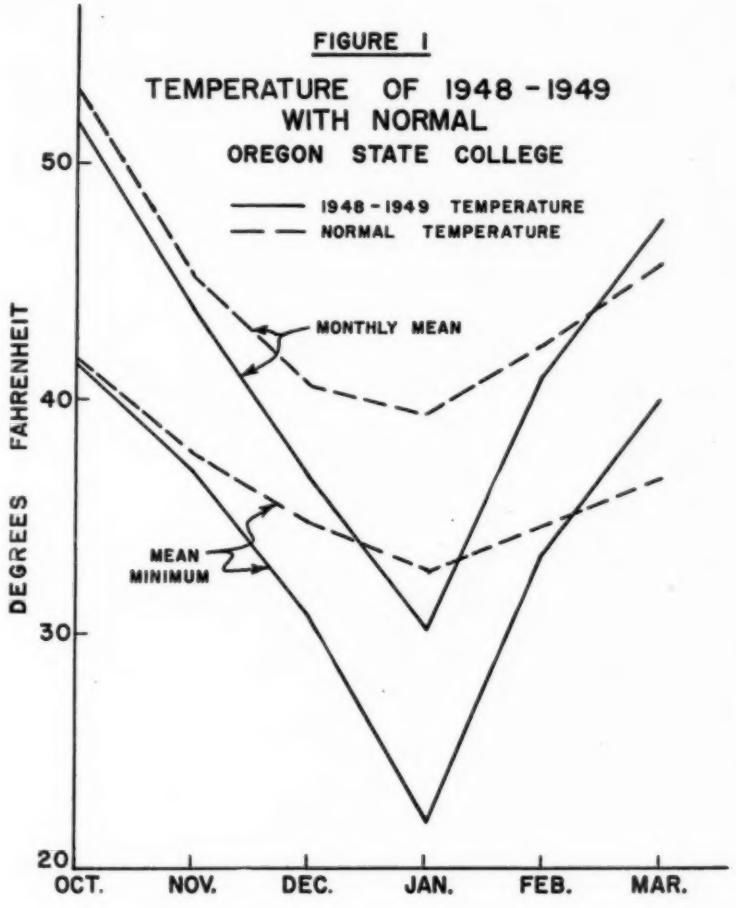
[2] Agronomist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, USDA. In cooperation with Oregon Agricultural Experiment Station.

[3] Numbers in parentheses refer to literature cited.



after having been well conditioned for bolting will usually produce a larger root and considerably more seed than similar roots fully induced for bolting. Similar behavior seems to occur if the plant is only partially conditioned for bolting. Such roots classified by Owen (2) as semi-vegetative continue to develop root tissue at the same time as they are developing seed stalks. Such a contingency is dependent on the beets not being so vegetative as to fail to develop normal seed stalks. Stout (5) discussed the accumulation of substances which cause bolting in beets and presented evidence that it is of a chemical nature. Chroboczek (1) showed that the thermal induction stimulus in beets is concentrated in the crown.

Field Observations

In late February, 1949, in western Oregon many beet fields had a very discouraging appearance. Several were abandoned as unsuited for profitable seed production. Plants appeared to be too badly frozen to recover. The larger, earlier planted beets suffered most. Subsequent events, however, showed that these early appearances were misleading. Nearly all roots not completely killed eventually recovered and produced normal seed stalks. Fig. 2 shows some typically frosted roots in the early spring and Fig. 3 shows the typical appearance following seed production. In most cases the root bridged around the damaged tissue with new growth.

Seed yields of many of the commercial fields which were in top rank condition in the fall and suffered most from frost damage ranged from 3,500 to 5,000 pounds of seed per acre. In previous years yields of the best fields had been 2,000 to 4,000 pounds. Data are not available but observations indicated that the average root size at harvest time was considerably above normal. It was also apparent that in most fields the plants showed more tendency than usual to continue vegetative growth after harvest. No data are available as to relative defoliation.

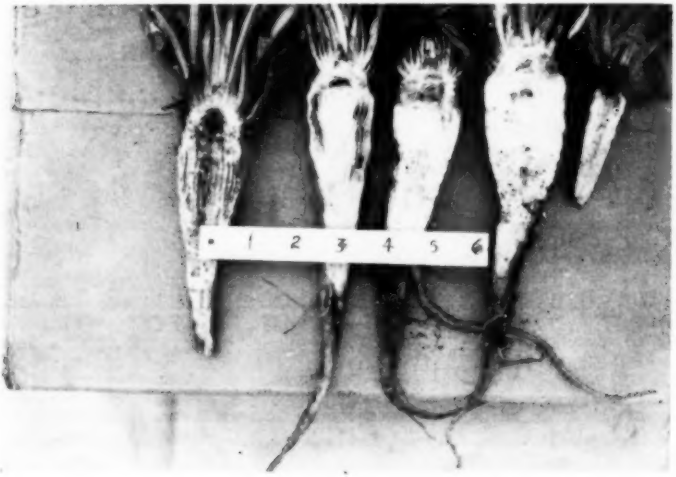


Figure 2. Appearance of some of the larger beet roots in early spring after growth was resumed, showing badly frosted tissue around the crown.

Discussion

During a considerable portion of the winter the temperature was either above or below the optimum for thermal induction of flowering. Under such conditions it may be that an insufficient amount of the postulated chemical was formed in the plants to produce the degree of thermal induction usually obtained in this area. As a result the plants remained in a partial or semi-vegetative condition, thus producing more vigorous seed stalks.

If the thermal induction substance is of a chemical nature and is concentrated in the crown tissue, as has been postulated, freezing and subsequent sloughing away of a portion of the crown tissue might conceivably remove some of it. Such a circumstance would also tend to hold the plants in a semi-vegetative condition.

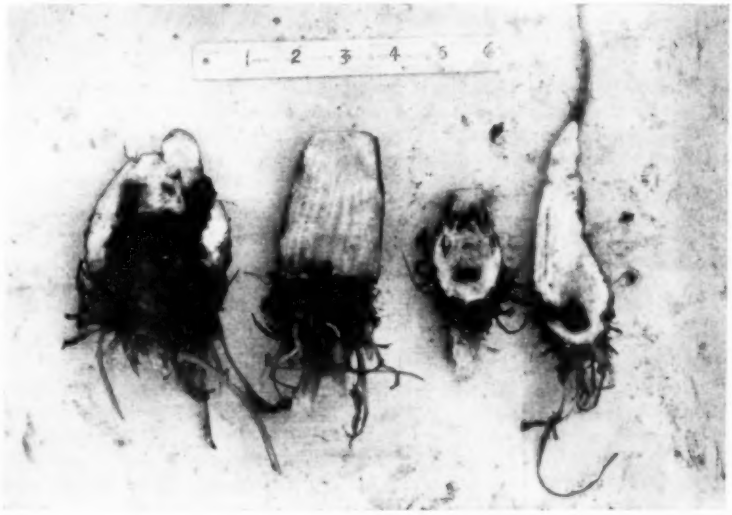


Figure 3. Appearance of some frosted beet roots after having grown normal seed stalks.

Summary and Conclusions

Due to exceptionally cold weather in western Oregon in the winter of 1948-49 sugar beets being overwintered in the field for seed production were badly frozen.

When growth resumed in late February a high percentage of the roots had more or less decayed crown tissue from the freezing. Appearances indicated that the decay might spread and destroy the whole crown.

Contrary to expectations most beets recovered, made normal seed stalks and better than average seed yields.

The suggestion is made that the improved seed yield was due in part to the beets being semi-vegetative. Under such conditions new root tissue may continue to develop while seed stalk formation takes place; whereas, under conditions of more complete thermal induction, no further root growth takes place after spring growth has resumed.

The lack of complete thermal induction may have been due to insufficient time during the winter when the temperature was optimum for forming the necessary bolting factor substance, or possibly due to loss of such substance from the crown tissue after it had been formed as a result of freezing injury.

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Viability of Sugar Beet Seed Held in Cold Storage for 22 Years

D. A. PACK AND F. V. OWEN[1]

On March 8, 1928, two 5-pound sugar-beet-seed samples were placed in a commercial refrigeration cold-storage house at Salt Lake City, Utah, by the senior writer. The seed used was the German variety, Braune, reproduced at St. George, Utah, in 1927. This seed was run over a 7/64-inch screen to take out the very small seed balls. The seed was placed originally in two metal containers, one of which was sealed. By 1938 these containers rusted and became perforated with holes. At that time the seed was transferred to cloth sacks. Temperatures over the period of years have ranged from +10° F. to —10° F. but have been held constantly below freezing.

Germination records over a period of years are shown in Table 1. Some variation is expected in these results due to small differences in methods of sampling and technique of running the tests. In 1942 Stout and Tolman's improved method[2] of preliminary washing in running water was initiated. Temperatures during germination tests varied from 20° C. to 25° C. but all tests were continued for 14 days to obtain complete germination from all seed balls. Duplicate 100-seed-ball samples were germinated at all dates. After 22 years the tests showed 75 percent germination.

It was thought advisable to obtain information on the vigor of plants grown from the seed held in cold storage for as long as 20 years. Measurements of seedling vigor were considered but observations showed that the old seed produced seedlings with approximately the same vigor as seedlings from current commercial sugar beet seed lots. Any significant differences, therefore, would have required a very precise technique. Considering the difficulties of such technique it was deemed advisable to make a test under field conditions. Table 2 shows results obtained by G. K. Ryser giving comparisons between the seed held in cold storage and the seed from the curly-top-resistant variety US 22/3 produced at Avon, Utah, in 1946. Two-row plots 60 feet long were replicated twice again in 1948. In 1949 two-row plots 29 feet long of each variety were replicated three times. These field

Table 1.—Germination of sugar beet seed held 21 years in cold storage (1928-1949).

Date	Length of storage years	Percent germination	Tested by
1928	0	83.5	D. A. Pack
1942	14	86.5	Myron Stout
1947	19	85.0	W. J. Musser
1948	20	75.0	Betty Nielsen
1949	21	81.0	Betty Nielsen
1950	22	75.0	C. H. Smith

[1] The senior author was formerly Physiologist, and the junior author is now Senior Geneticist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

[2] Factors affecting the germination of sugar-beet and other seeds, with special reference to the toxic effects of ammonia.—Myron Stout and Bion Tolman. Journal of Agricultural Research 63 (12): 687-713, 1941.

tests were made at Granger, Utah, on soil with good fertility, which produced a luxuriant growth of foliage. The data shown in Table 2 substantiate the field observations regarding the normal vigor of plants grown from seed held in cold storage for the length of time indicated. There was no indication at any time that plants grown from the seed stored 19 to 21 years were deficient in vigor.

Utilization of Information by Plant Breeders

It is common knowledge that the viability of sugar beet seed under storage at low humidity is much superior to storage under high humidity. At Salt Lake City the humidity is low and sugar beet seed stores well for a period of ten years or more. After about 15 years, however, the germination appears to drop rapidly. In 1948 a test was run with seed from some curly-top resistant varieties which had been stored for several years under normal sugar beet seed storage conditions. Seed of variety U.S. 1 stored for 19 years showed 27 percent germination as compared with an original germination of about 80 percent. U.S. 33 stored for 15 years gave 59 percent germination. A sample of the same U.S. 33 seed placed in cold storage in 1938 showed 96.5 percent germination in 1948, which is comparable to the original germination.

The sugar beet breeder is vitally interested in seed storage methods which will prolong the normal viability of his breeding stocks. Evidence indicates that storage in commercial cold storage houses offers one possibility. One drawback with some of the present cold-storage plants is the fire hazard involved. The original storage house in which the seed was first placed at Salt Lake City in 1928 burned in 1949. Fortunately, the seed had been transferred to a new storage house, but at this new location there is some fire hazard, too. Artificial drying and storage in partial vacuum or in carbon dioxide gas may supplement the desirable effect of low temperature. One of the original five-pound seed lots was sealed in 1928 but unfortunately the seal was broken by rusting of the metal container.

The storage test begun in 1928 will be continued and interest in the results will no doubt increase as the years go by. The writers wish to acknowledge and extend thanks to those who conducted the germination tests and to Mr. George K. Ryser who conducted the field comparisons.

Table 2.—Yields from seed held in cold storage for 19, 20 and 21 years, compared with the 1946 seed crop of the commercial curly-top-resistant variety U.S. 22/3—By G. K. Ryser.

Year tested	Acre Yield, Beets			Acre Yield, Gross Sugar		
	U.S. 22/3 seed		Cold storage Braune seed	U.S. 22/3 seed		Cold storage Braune seed
	Tons	Percent[1]	Percent[1]	Pounds	Percent[1]	Percent[1]
1947	35.1	100	96	11,660	100	87
1948	21.2	100	118	6,390	100	102
1949	21.8	100	94	6,104	100	98
Average		100	103		100	96

[1] Figures in percent of U.S. 22/3 yields.

Summary

Sugar beet seed was placed in a commercial refrigeration cold-storage house in 1928. In 1950, after 22 years, the percentage germination of this seed was still 75 or about 10 percent less than the original germination in 1928. Agronomic tests in 1947, 1948 and 1949 indicated normal vigor and sugar content after 18 to 20 years storage.

Some Effects of Plant Growth Regulators on Bolting and Other Responses of Sugar Beets

CHARLES PRICE, WILLIAM S. STEWART, AND LOUIS C. ERICKSON[1]

Introduction

In a sugar beet crop grown for the production of sugar, development of seed stalks by the plants, called "bolting," is highly objectionable. Commercial varieties of sugar beet are biennial in growth habit but in fall and winter plantings, as made in California, enough thermal induction may occur to bring about bolting in a very considerable percentage of plants. If the bolting occurs early in the growing period the roots remain relatively small and become so fibrous or woody as to make slicing at the factory for processing into sugar very difficult. If the plants produce tall stalks and seed there is usually a decrease in the sugar content of the root. If mature seed is produced then in subsequent seasons sugar beets may persist as weeds. A most serious objection to the occurrence of bolting in sugar beets grown for sugar is the interference of the seed stalks, which may be three to six feet or more in height, with the operation of mechanical harvesters.

Control of bolting by breeding varieties low in bolting tendency has been undertaken and with very encouraging results. Other means of controlling bolting may also have some value in meeting the problem.

Flowering appears to be a hormone-controlled process (5)[2]. It has been observed that high auxin concentrations in plants can inhibit flowering (2, 4). Inhibition of bud growth by auxin and other plant growth regulators is well known (1). A 50 ppm. 2,4-D spray was reported to slightly retard elongation of seedstalks of celery plants which had been thermally induced (3). On the basis of these considerations, experiments were initiated to study the effect of plant growth regulators on bolting of sugar beets.

Method and Results

Exploratory tests were made in 1947 to determine the effects of various growth regulators on bolting of sugar beets. The regulators used in various forms and concentrations were: 2,4-dichlorophenoxyacetic acid (2,4-D); ortho-chlorophenoxyacetic acid; para-chlorophenoxyacetic acid; and tri-iodobenzoic acid. The most promising results were obtained with the lower concentrations of 2,4-D.

On the basis of these results more extensive trials were made with 2,4-D in 1948 on sugar beet variety U. S. 22 (S. L. 622), which bolts readily, and strain S. L. 753, which does not bolt readily. The beets were planted July 6, 1948, so that no bolting occurred until the following spring. Drenching

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[2] Numbers in parentheses refer to literature cited.

foliage sprays of 2,4-D, as the triethanolamine salt, were applied to separate groups of plants on September 24, October 21, December 2, January 28, and March 18. These were replicated five times with approximately 100 plants per replicate or 500 per treatment. The September application was made at 50 ppm. 2,4-D; subsequent applications were at 5 ppm.

When the results were recorded on April 11, 1949, plants classed as "early bolting" were those which had seedstalks at least three feet in length; those classed as "late bolting" had seedstalks less than three feet. "Non-bolting" plants showed no evidence of seedstalk formation but were completely vegetative.

Table 1.—Effect of 2,4-dichlorophenoxyacetic acid Foliage Spray on Bolting, Growth, and Sucrose Content of Sugar Beet Variety U. S. 22 (S. L. 622). Bolting counts based on 500 plants, other determinations on average of 50 plants. Sugar beets planted July 6, 1948; harvested July 7, 1949.

	Spray applied on—						L. S. D.[1]	
	None	9-17-48	10-21-48	12-4-48	1-28-49	3-18-49	5%	1%
Concentration 2,4-D, ppm.	0	50	5	5	5	5		
Early bolting plants, percent	97.0	58.4	80.2	75.6	72.2	89.2	13.8	18.9
Late bolting plants, percent	3.0	36.2	19.8	24.4	27.8	10.8	13.8	18.8
Total bolting plants, percent	100.0	94.6	100.0	100.0	100.0	100.0	3.6	5.0
Non-bolting plants, percent	0.0	5.4	0.0	0.0	0.0	0.0	3.6	5.0
Fresh weight, tops, per plant, gms.	1230	669	1045	.....	.....	.....	90	131
Fresh weight, roots, per plant, gms.	763	601	693	.....	.....	.....	83	121
Sucrose in root, percent	10.02	9.56	10.52	.....	.....	.....	0.54	0.79
Sucrose per root, grams	76.1	57.3	73.0	.....	.....	.....	8.8	12.8
Apparent purity coefficient, percent	85.1	79.5	87.5	.....	.....	.....	1.8	2.6

[1] Least difference required for significance.

The counts for the two varieties as made on April 11, 1949, for numbers of plants bolting and the type of bolting are given in Tables 1 and 2. On the basis of the performance of the unsprayed check, early bolting of U. S. 22 was reduced significantly by the 50 ppm. spray, the data showing a reduction from 97.0% to 58.4%. The 5 ppm. sprays applied in October, December, or January, reduced early bolting from 97.0% to about 75%, an amount significant at the 5% level. The data for variety S. L. 753 (Table 2) showed that the 50 ppm. spray reduced early bolting from 37.4% for the non-sprayed check to 5.8%, a highly significant effect. The 5 ppm. sprays in October, December, or January, reduced early bolting of this variety from 33.4% as shown by the check to about 14%, the effects being highly significant.

In both varieties it appears that the 50 ppm. 2,4-D sprays prevented seed stalk formation in some plants. The 5 ppm. 2,4-D sprays applied to U. S. 22 apparently delayed but did not prevent seed stalk formation since 100% of the plants eventually produced seed stalks. Similarly, S. L. 753 plants receiving 5 ppm. did not differ in total plants bolting from those not sprayed, but initiation of bolting was later.

The plots were harvested on June 7, 1949. Samples of 50 plants per treatment were taken at random from the non-sprayed, and from the plots sprayed September 17, 1948, and October 21, 1948, for determinations of top and root weights and for sucrose determinations. Top weights in both varieties of the plants sprayed in September with 50 ppm. 2,4-D and in October with 5 ppm. 2,4-D, were reduced significantly in comparison with non-sprayed plants. Root weights were reduced significantly by the 50 ppm. spray given in September, but this reduction was not in proportion to the severe effects on the tops. Root weights were significantly different from those of non-sprayed plants as a result of the 5 ppm. 2,4-D spray applied in October.

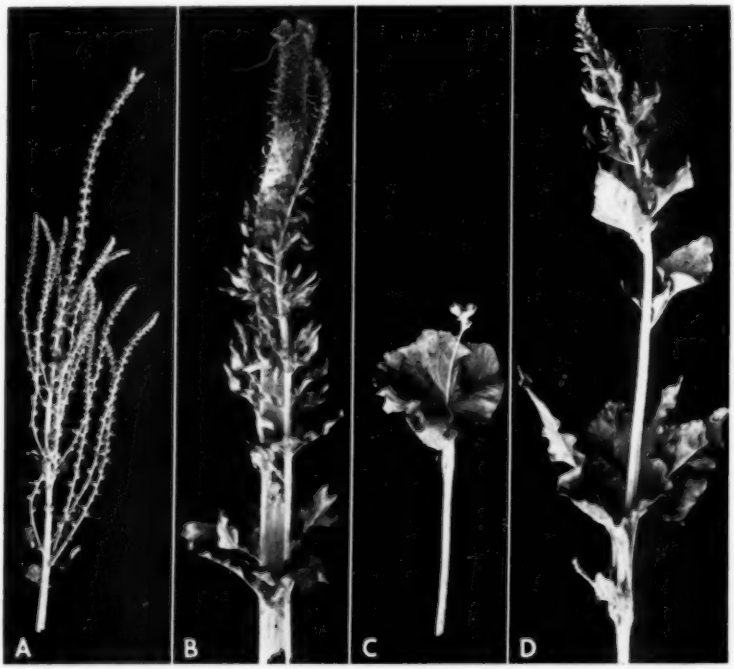

Figure 1. Seed stalks of sugar beet strain S. L. 759. A is normal; B, C, and D show various types of fasciation in response to a 50 ppm. 2,4-dichlorophenoxyacetic acid foliage spray applied December 2, 1948. Seed planted July 6, 1948. Stalks photographed May 9, 1949.

The sucrose percentage of roots of the sugar beets sprayed in October with 5 ppm. 2,4-D did not differ significantly from that of the non-sprayed beets; in both strains, plants sprayed in September with 5 ppm. 2,4-D had their sucrose quality reduced significantly. The same types of response are shown when comparisons are made with respect to total sugar per root; however, reduction in size of root for variety S. L. 753 was not compensated adequately by increase in sucrose percentage, so that the sugar per root is significantly less (5% level) than in the unsprayed check. Analyses were not made of the beets sprayed at other dates.

Table 2.—Effect of 2,4-dichlorophenoxyacetic Acid Foliage Spray on Bolting, Growth, and Sucrose Content of Sugar Beet Strain S. L. 753. Bolting counts based on 500 plants, other determinations on average of 50 plants. Sugar beets planted July 6, 1948; and harvested June 7, 1949.

	Spray applied on—						L. S. D.[1]	
	None	9-17-48	10-21-48	12-2-48	1-28-49	3-18-49	5%	1%
Concentration 2,4-D, ppm.	0	50	5	5	5	5		
Early bolting plants, percent	33.4	5.8	13.4	13.0	15.8	12.2	7.2	9.9
Late bolting plants, percent	57.8	24.2	76.2	77.2	74.4	81.0	9.2	12.5
Total bolting plants, percent	91.2	30.0	89.6	90.2	90.2	93.2	6.9	9.5
Non-bolting plants, percent	8.8	70.0	10.4	11.8	9.8	6.8	7.7	10.6
Fresh weight, tops, per plant, gms.	1374	462	1159	----	----	----	132	192
Fresh weight, roots, per plant, gms.	770	638	690	----	----	----	83	121
Sucrose in root, percent	13.52	10.94	13.64	----	----	----	0.45	0.66
Sucrose per root, grams	103.6	69.7	91.4	----	----	----	10.6	15.4
Apparent purity coefficient, percent	89.4	77.7	89.6	----	----	----	0.9	1.3
Net sucrose per root, grams	92.5	54.2	81.7	----	----	----	25.4	36.9

[1] Least difference required for significance.

Among the 500 plants receiving the 50 ppm. spray, two showed no visible response. These were marked for further study of possible 2,4-D resistance. On December 2, 1948, approximately 1,200 plants of strain S. L. 759 were sprayed with 50 ppm. 2,4-D and 28 plants which showed no visible response were selected for further study and possibly for breeding for 2,4-D resistance.

In addition to delayed bolting, it was also observed that: (1) Within 48 hours after spraying with 5 ppm. 2,4-D there was a slight twisting of some of the petioles; (2) the 50 ppm. 2,4-D spray induced severe epinasty and longitudinal cracking of some petioles; (3) plants sprayed with 50 ppm. 2,4-D in September or December, 1948, had various types of seedstalk fasciation when bolting occurred the following spring (Fig. 1). In some cases petioles were fused to varying degrees and occasionally formed a cylinder through which the seed stalk emerged. In other cases leaf blades were forked or multiple tipped (Fig. 2). On harvesting June 7, 1949, masses of branched lateral roots, which had died back nearly to the tap root, were observed on the plants sprayed with 50 ppm. 2,4-D in September or December, 1948 (Fig. 3).

Summary and Conclusions

Exploratory tests in 1947 on the effect of several plant growth regulators on bolting of sugar beets indicated that a foliage spray containing a low concentration of 2,4-D delayed bolting.

Additional studies were made in 1948 consisting of a foliage spray of 5 ppm. 2,4-D applied to replicated plots of sugar beets at each of the following dates: October 21, 1948; December 2, 1948; January 28, 1949, and March 18, 1949. Another set of plots was given a 50 ppm. 2,4-D spray on September 17, 1948. Beets of variety U. S. 22, which bolts readily, and of

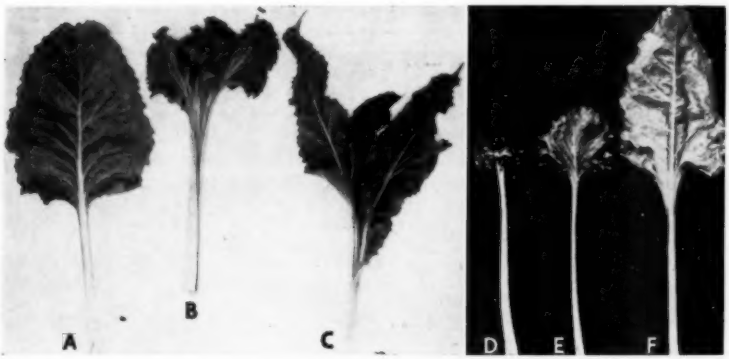

Figure 2. A and F, leaves from non-treated plants; B, C, D, E, various leaf deformities induced by 2,4-D applications to sugar beet variety U. S. 15.

strain S. L. 753, which does not bolt readily, were used in these tests. The plots were planted July 6, 1948, observed for bolting on April 11, 1949, and harvested June 7, 1949. All treatments delayed bolting significantly except the one applied in March to plants of variety U. S. 22, and even in that case the data closely approached significance. The 50 ppm. 2,4-D spray applied in September was the most effective in reducing bolting but it also lowered the sucrose percentage and the sucrose per root of plants of strain S. L. 753 and U. S. 22 below the values obtained in the unsprayed plots of these varieties. The differences were significant or approached significance. The 5 ppm. 2,4-D spray applied in October did not lower significantly the net sucrose per root of beets of variety U. S. 22 but it lowered significantly the net sucrose per root of plants of strain S. L. 753 below the values for the unsprayed plots. It is emphasized that further studies are necessary before growers' tests would be justified.

Along with the retarding effects on bolting, certain other plant responses were noted in the treated sugar beets. The 50 ppm. 2,4-D spray induced a severe epinasty and longitudinal cracking of the petioles on most of

the plants. In a few instances plants failed to have these responses. These individuals have been selected for further study and possible breeding for 2,4-D resistance. In addition, nearly all of the U. S. 22 and S. L. 753 plants sprayed with 50 ppm. 2,4-D in September, or the S. L. 759 plants sprayed in December with 50 ppm. 2,4-D, showed very striking seed stalk fasciations of various types. At harvest the beet root had masses of branched lateral roots which had died back nearly to the main root. Apparently 2,4-D is not specific for bolting. The reduction in the number of plants producing seed stalks is only one response to 2,4-D, and the other responses appear for the most part to have been undesirable from the standpoint of sugar production.

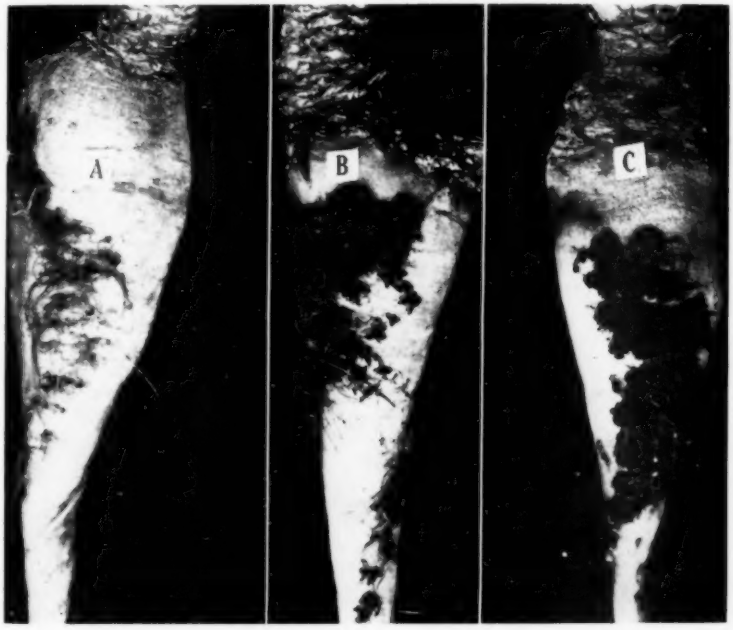

Figure 3. Beet from non-treated plant (A) and from a plant sprayed with 50 ppm. 2,4-D in September (B) or December (C), 1948, showing masses of branched lateral roots which died back nearly to the main root. Photographed on June 7, 1949.

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Chemical Methods for Breeding Sugar Beets

H. W. DAHLBERG[1]

When we speak of chemical methods we, of course, include two important determinations—the determination of sugar and purity. Sugar is by far the most important single component in beets, and we believe it is of value to determine any other chemical compounds which have a bearing on sugar content.

Our research department began using chemical methods for selection in 1931. At that time the determinations made were chiefly-total nitrogen, harmful nitrogen and ash content. Later electrical conductivity was substituted for ash determinations. Studies were made on the proportions of certain non-sugars which were eliminated in the factory process and the proportions which carried through into molasses. These studies gave us breeding lines which produced juices of somewhat higher purity than were obtainable from European seed varieties.

There are various ways of selecting for high sugar and high purity, and occasionally an unusual method of selection gives unexpected results. This is true of a selection we made in 1937, when we selected a small percentage of surviving beets from a Great Western commercial variety which had been planted in the fall in northern Colorado and subjected to very low temperatures during the winter. The main results of this selection were to give us a new variety, G.W. 201, which, compared with the parent variety, had the following characteristics:

Higher frost resistance
No loss in tonnage
An increase of 0.6 to 0.7 points in sugar content
A purity which averages slightly higher than other excellent Great Western varieties
Minimum sodium content—.023 to .035% Na—which is low for highly mineralized soils

In 1948 we began using a flame photometer in connection with selection of beets with minimum sodium content and during the past year and a half we have studied the sodium content of beets rather intensively. We find the same as some of the European investigators that there is a strong negative correlation between the sugar content of the root and the sodium content of the root. In a very large number of determinations on individual beets we found this negative correlation to be as high as —.830. As yet we do not know whether the sodium determination will be an important tool in selecting for higher sugar, but we have in progress an experiment which should give us valuable information on this point. At present we believe it is a very worth while determination, because a low sodium content not only normally indicates a high sugar content, but also tends to give a beet of higher purity.

[1] Director of Research, Great Western Sugar Co., Denver, Colo.

Van Ginneken found from a large number of analyses of many types of Holland beets that there were major differences in the sodium content of fodder beets and "half-sugar" beets, as compared with standard varieties of sugar beets. The former may contain two to three times as much sodium as do the improved varieties of sugar beets, and, of course, are very low in sugar content.

It seems quite probable that the white Silesian beet, the ancestor of most or all sugar beets, contained some blood lines going back to fodder beets or mangel-wurzels. It, therefore, seems logical to me that if we select beets of low sodium content we may eliminate more rapidly some of the undesirable genes originating in fodder beets. If this theory should be correct we may be able to reduce variations in sugar content by developing varieties of low sodium content.

In our research laboratory we have done a great deal of work on the pigments in sugar beet leaves, chlorophyll, xanthophylls and carotene, in the hope that thereby we might be able to select beets of high photosynthetic efficiency. We have learned something about the relationships of the different pigments but have not been able to find large differences between varieties of varying sugar content. We believe that, at some time in the future when the chemistry of photosynthesis is more completely worked out, the analysis of leaf pigments may be of value. At present, the necessary determinations are too time-consuming, and we do not know enough about the action of the many pigments in the photosynthetic process.

At the present time we consider the following determinations to be the most useful in connection with breeding work:

Percent Sugar	**Percent Total Nitrogen**
Purity	**Percent CaO + MgO**
Percent Sodium	**Percent Ash**

The sodium content, percent on ash, should be low, and the sum of CaO + MgO, percent on ash, should be high for beets of high quality. Under our conditions of soil and climate, the figures are about as follows:

Percent on Ash

Na_2O — 6 to 7%
CaO + MgO — 18 to 23%

Chmical breeding methods will not come into their own until the selection material can be grown under uniform conditions of light, temperature and nutrition, such as can be obtained only when beets are grown in nutrient solutions. When beets are grown in soil the chemical constituents are too much influenced by variations in soil composition and fertility. We, therefore, during the next few years hope to grow a population of beets in nutrient solutions and make more chemical determinations for selection than we are now justified in doing.

Summary

Chemical breeding methods are considered to be of value for the purpose of securing juices of higher purity and also for the purpose of increasing sugar content. It is our belief that selection for minimum sodium content may be of some value in reducing variability of sugar content and eliminating low sugar individuals.

Soil Structure in Relation to Beet Growth

HENK RIETBERG[1]

A Problem in Plant Improvement

There was a time in the Netherlands when many people did not give much attention to the soil and soil problems other than from point of view of fertilization and plant rotation. They more or less considered the soil only as a medium from which the root takes water and nutrient substances. We have learned now that there are many other factors in the soil which influence plant growth. A number of these factors may be grouped together as "soil structure." A discussion of soil structure should include its influence on sugar beet growth and development, but at this time I will limit it to experiences with sugar beets which may be useful for consideration by breeders.

Our work of the last years has shown us that the development of the beet is influenced strongly by soil structure and that the roots of the sugar beet react to variations in soil structure which we do not see with the naked eye and which we cannot at present measure with our instruments.

There is, however, a tendency in certain quarters that I should like to mention as I consider it as being dangerous from an agricultural point of view. Some of our soil structure enthusiasts are inclined to overrate the influence of soil structure and even go as far as to tell us that if soil structure were better there would be no plant diseases, no insect pests at all. If such theories were to prevail, along with the overexploited humus theory, the farmer would be inclined to neglect necessary agricultural and hygienic measures—a course that could only lead to serious disappointments.

Among the problems for the Dutch beet grower excessive tare, caused by sprangled or fangy roots, is a major one. Under our usual soil and climatic conditions during the harvest period loss of yield and excessive tare constitute limiting factors affecting efforts to mechanize the sugar beet harvest.

As our Institute has variety trials all over the beet districts of the Netherlands it is easily understood that we also turn our attention to the problem of forked, misshapen sugar beet roots. Striking differences in root size and shape were found for the same series of varieties when grown on different soil types as, on basis of our earlier observations, we expected would be the case.

But going more closely into details we found that on a field with good structure there was not much difference in root development between the varieties. Each conformed well to the shape characteristic for the variety and developed practically no side roots or fangs. On soil of poor structural condition, however, some varieties grew nicely shaped roots but others gave only stunted roots with many fangs.

[1] Instituut voor Rationele Suikerproductie Bergen op Zoom.

We first attributed these differences to the fact that in one case the breeder probably had paid more attention to the root shape than in the other case. As this factor was of general interest for our Dutch beetgrowers we discussed this problem with two of our most important Dutch sugar-beet breeders without coming to a conclusion as we found that each paid much attention to the shape of the root in his breeding work. Then we visited the breeding stations and found that one was located on a very fine soil (a young silt of maritime origin with a high percentage of $CaCO^3$ and sufficient organic matter) where the soil structure was excellent, whereas the other was located mainly on clay soil with a poor structure.

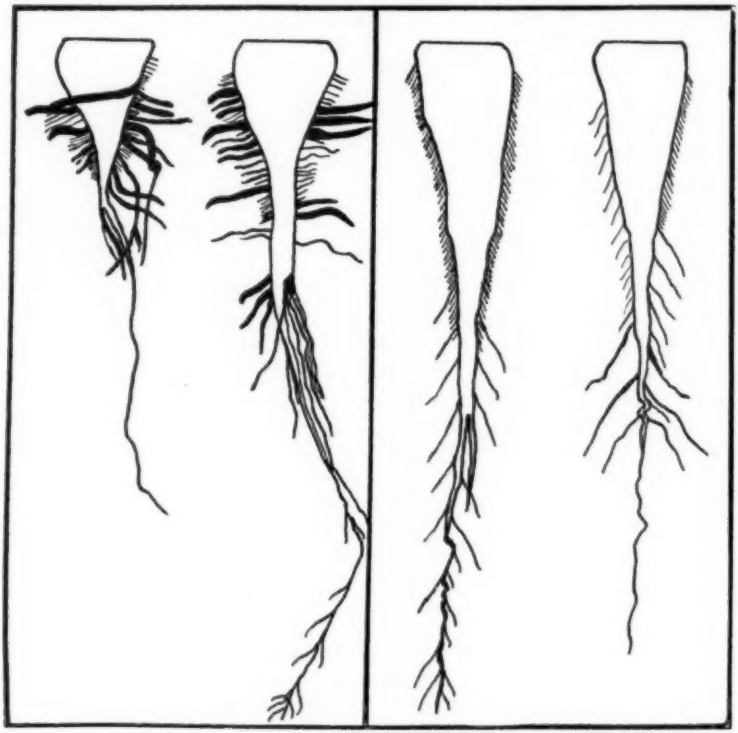

Figure 1. Two varieties of sugar beet as grown on a clay soil of poor structure (left half of this figure). Left: Seed from a breeding station located on soil of good structure. Right: Seed from a breeding station located on soil of poor structure. On soils of good structure both varieties react as at the right side of this drawing.

When we saw progenies of various mother beets tested on the soil with poor structure we came to the conclusion that here the plants were undergoing a very severe test with respect to root shape. On the other station, however, with its better soil the variation between progenies with regard to the development of fangy roots was only very small. When these beets were sown on a soil type with a poorer structure there was an unexpected development of sprangled roots. In contrast to this the beets from the station with poor soil structure developed good roots on practically every type of soil.

In the summer of 1949 we did more intensive work on the influence of soil structure on the shape of the root and on the growth of beets in general. We collected a great quantity of drawings and photographs and many interesting relations of soil structure to the development of beet roots could be discussed, but as most of these relations are agronomic rather than genetic I will only mention here that this work, which is still being continued, has fully corroborated our idea that the success of breeding for root shape is conditioned by the structure of the soil where the breeding work is done. Under the conditions prevailing in the Netherlands it will be necessary to test new strains and hybrids extensively on a soil with poor structure if disappointments with otherwise promising new varieties are to be avoided. Since fangy roots are a limiting factor preventing the Dutch farmer from making much advance in mechanizing his beet harvest this problem will continue to be of great importance.

There are also other points in which soil structure interferes with the work of the breeder. For instance, bolting under the climatic conditions of the Netherlands is mostly induced through a spell of cold weather during the period when the seed is germinating in the soil. Variations in soil structure have their influence on the bolting. Soils of poor structure retard germination and this prolonged period of sprouting tends to increase the period of exposure to cold. Readings of soil temperature at the depth where the seed is planted often show a few degrees centigrade difference between good and poor structure.

In many years we have practically no bolters, but in 1949 conditions were favorable for bolting and we saw striking differences in bolting not only between varieties but also in the distribution of bolters throughout a field. The same was seen in trial fields laid out by breeders to test their strains for resistance to bolting.

It is our idea that, because of soil heterogenecity, the exposure to cold in the field tests in our country is not sufficiently uniform for the breeders to make trustworthy selections for resistance to bolting based on their field trials.

We find also that there is much variation in emergence of seed of various varieties, even if the tests in the laboratory show the same vitality. Our work on this subject is not yet finished but we have indications that

even in the seedling stage there are important differences in plant reaction not only to temperature but also to soil structure. This point has interested us very much because rapidity of emergence and first growth have far reaching significance. Twenty-five years of research work have proved clearly that in the Netherlands at the end of June, i.e., eight to ten weeks after emergence, we are able to predict whether we will have an average, a low or a high root yield. Therefore, the rapidity of growth in the period till the end of June is more or less decisive for the final beet yield.

If we want to have varieties for early drilling on soils of proper structure which will emerge rapidly and give an early sturdy growth we will have to pay more attention to this part of the problem and include it in our breeding objectives.

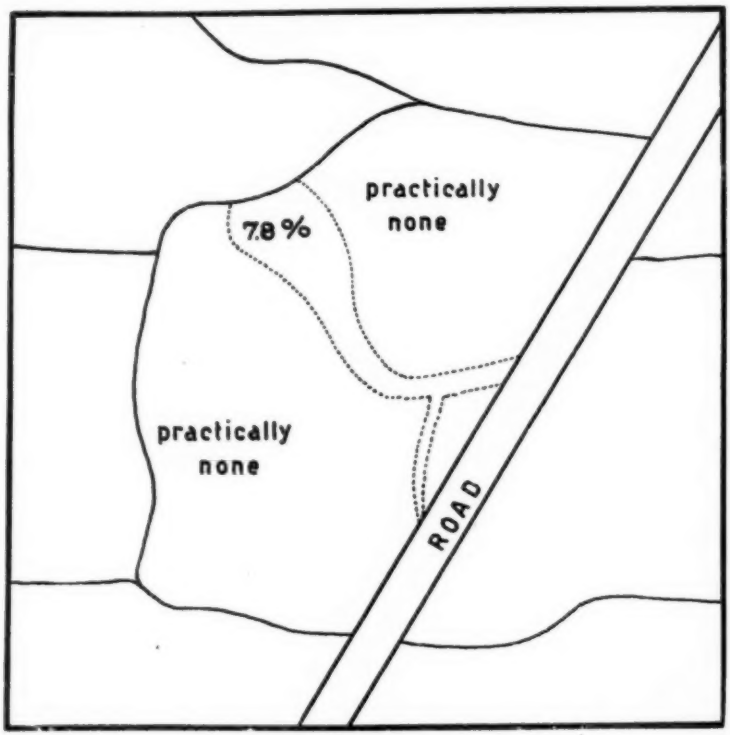

Figure 2. Diagram to illustrate influence of soil structure on bolting. The whole field was prepared and planted at the same date with the same variety. Between the dotted lines the soil was of poorer structure. Bolting here reached 7.8%, with practically none elsewhere in the field.

Summary

A number of factors in the soil influencing plant growth may be grouped together as "soil structure." In this paper the discussion has been restricted to information useful for sugar beet breeders.

1. Under the conditions prevailing in the Netherlands the success of breeding for rootshape is conditioned by the structure of the soil where the breeding work is done.

2. Field tests for bolting resistance under our conditions are not sufficiently trustworthy due to the influence of soil heterogenecity on bolting.

3. In breeding varieties for early drilling more attention will have to be paid to soil structure in relation to emergence and early growth.

Sodium and Potassium Content of Sugar Beet Varieties in Some Western Beet Growing Areas

C. W. DOXTATOR AND F. R. CALTON[1]

Breeding for improvement of sugar beets in the past has been largely confined to the factors of yield, sucrose percentage and disease resistance, since these characters were of first importance in American-developed varieties. Recently however, non-sugars in beet juice have commanded attention since high purity in beets is essential to maximum extraction of sugar.

The literature contains numerous references to non-sugars but very little data which are related directly to a breeding program. Contributions such as those of Zitkowski et al (6)[2] and of Ness (3) have established average values for the various non-sugar constituents with respect to average sugar beet varieties. Wiklund (5) gives a very detailed discussion of the effect of various non-sugars on factory operations with numerous references. All of these indicate the need for improving beet quality. Smolenski and Zalenski (4) have investigated differences in the chemical composition of high sugar and high tonnage type beets; and Dahlberg (1) has reported results of breeding for high purity type varieties.

Early in 1949 plans were made by the American Crystal Sugar Company to enlarge its breeding program with the objective of further improving the purity of juice in sugar beet varieties. A study of sodium and potassium was chosen to initiate the work since, in spite of the importance of these minerals, practically no direct information was available. To a large extent this lack of information could be traced to the expense involved in sodium and potassium determinations by conventional methods. Now, however, with the advent of flame spectrophotometry involving low temperature excitation and direct photometric measurement, such analyses can be placed on a routine basis in the hands of only semi-skilled analysts. Also an analysis is rapid enough so that sufficient data can be obtained for interpretation by the conventional statistical methods commonly used in breeding programs.

This paper reports the results to date on Na and K content between and within varieties tested in different areas.

MATERIALS AND METHODS

Sample Preparation

The samples tested fall into two groups with respect to preparation for analysis: A. Those from widely separated areas which could not very well be shipped in a wet form, and, B. those from a single area where the mineral analysis could be made parallel with the usual sucrose determination.

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[1] Plant Breeder and Experimental Chemist, respectively, American Crystal Sugar Company, Rocky Ford, Colo.

[2] Numbers in parentheses refer to literature cited.

Plot and strip test samples were prepared as follows: 5 gms. of freshly rasped pulp were weighed rapidly on a watch glass, transferred into a 1-oz. wide mouth bottle, dried at 105° C. for 4-8 hours, capped with screw caps having vinylite liners, labelled and shipped to the central laboratory. The bottles had been washed, then soaked in dilute HCl, rinsed with distilled water and dried before use; the caps were rinsed with distilled water. In almost every instance the pulp dried to a hard mass on the bottom of the bottle.

In the central laboratory the dried pulp was softened in the bottle by covering with about 10 ml. of distilled water and allowing to soak for several hours. Contents of the bottle were then transferred quantitatively to a 50-ml. flask and made to volume with distilled water. After mixing, allowing to stand for about an hour and then remixing, the sample was filtered and the extract tested in a flame photometer.

When all samples making up a particular test were rasped at the central laboratory, the customary normal weight sugar solution could be used. According to this procedure 26 gms. of freshly rasped pulp were weighed rapidly into a capsule, 177.0 ml. of distilled water and approximately 0.6 gm. of Horne's dry lead added, the capsule covered, shaken, allowed to stand 30 minutes, shaken again and filtered. To each filtrate was added 2 drops of glacial acetic acid prior to testing in the flame photometer.

Sample Analysis

All samples as prepared above were tested for both sodium and potassium using the Beckman flame spectrophotometer (2). Instrument settings were as follows: (a) for sodium, wave length 589 m mu, slit .15 mm, sensitivity about 1½ turns from full clockwise position, red-sensitive phototube, gas 4 cm., oxygen 42 inches, air 25 lbs. per square inch (b) for potassium, wave length 767 m mu, slit .02 mm, sensitivity about 3 turns from full clockwise position, red-sensitive phototube, gas 4 cm., oxygen 36 inches, air 25 lbs. per square inch. Because this instrument sprays the sample into the flame after first drawing the sample up through a fine capillary it was very important that all samples be free from suspended particles.

In actual operation the transmission scale was set to read 100 for an 80-ppm. sodium solution by adjusting the sensitivity dial slightly; then checked against a 40 ppm. sodium solution to insure conformance with calibration curve characteristics; and finally a group of samples run. Six samples were usually run consecutively before the instrument was rechecked. After rechecking against the 80 and 40 ppm. sodium solutions, the last sample in the previous group was tested again; if the difference in transmission exceeded two transmission scale units, the previously tested samples were retested in reverse order until a check was obtained. In all instances, difference in reading could be traced to restricted flow through the capillary and could usually be corrected quickly by blowing air back through the capillary. For potassium the reference standards were 300 ppm. and 150 ppm. Both the sodium and potassium standards were in the chloride form.

Although instrument reference points were relative to solutions of the pure salts, actual calibration curves were prepared from data for mixed salt-

sucrose solutions which more nearly approximated the sample extract. For sodium, the calibration curve solutions contained 40 ppm. calcium as $Ca(NO_3)_2$, 40 ppm. magnesium as $Mg(NO_3)_2$, 300 ppm. potassium as KCl and 2% sucrose plus varying amounts of sodium as NaCl; for potassium the calibration curve solutions contained 40 ppm. calcium, 40 ppm. magnesium and 2% sucrose as before, plus 80 ppm. sodium as NaCl and varying amounts ofpotassium as KCl. Choice of 80 ppm. sodium and 300 ppm. potassium for the 100° transmission scale settings was based on average data obtained by Zitkowski (6).

EXPERIMENTAL RESULTS

Differences Between Varieties

The first results obtained in the 1949 season were from a 4-variety non-replicated strip test west of Fowler, Colorado. Five samples, each of 15 beets, were taken from each variety strip at uniform distances down the field. Average percentages of sucrose, sodium and potassium by variety for this test are given in Table 1.

Table 1.—Sucrose, sodium and potassium percentages of 4 varieties grown in strip tests at Fowler, Colo., in 1949.

Variety	Sucrose	Na in Beet	K in Beet
	%	%	%
5-414-0	17.48	.0384	.2072
Amer. 1 Com'l	17.46	.0424	.2076
Amer. 3 LSR	16.40	.0606	.2038
3-428-0 (Check)[1]	13.56	.1352	.1986

[1] R & G Old Type, American increase

Due to the severe *Cercospora* leaf spot conditions, only resistant varieties produced a high sucrose percentage. Differences in Na percents were also very large with the most resistant variety lowest in sodium. There were no appreciable differences in K percent.

Tests for Na and K were next conducted on an 8-variety test planted in Latin square arrangement. Two samples from each plot were used for the tests. Yield data along with percentage of sucrose, sodium and potassium are given in Table 2.

Table 2.—Yield and quality of 7 domestic varieties and 1 European variety in a Latin square test, Rocky Ford, Colo., in 1949.

Variety	Tons Beets per Acre	% Sucrose	% Na	% K
1	25.80	14.59	.100	.234
2	25.46	14.69	.094	.247
3	25.59	14.52	.090	.270
4	23.77	14.97	.090	.222
5	24.97	14.01	.111	.272
6	24.00	14.43	.106	.209
7 (European)	24.45	13.70	.120	.258
8	22.39	14.74	.090	.209
Sign. Diff. (19:1)	1.67	.61	.019	.022
F value	3.78[2]	3.60[2]	2.89[1]	10.75[2]

[1] Significant beyond 5% point.
[2] Significant beyond 1% point.

Statistical analysis of the data indicates that reliable differences between varieties were obtained for yield and for sucrose, Na and K percentages. Differences in Na percents ranged from .090 to .120, the high sodium value being found in the European variety, which has the lowest sucrose percent. Potassium percents ranged from .209 to .272, with the lowest value being found in the variety lowest in yield and above average in sucrose percent.

Differences Between Areas

In the 1949 variety testing program of the American Crystal Sugar Company, 16-variety, 6-replicate plot tests had been planted at Rocky Ford, Colo., Mason City, Ia., Chaska and East Grand Forks, Minn., all of which had a check variety, American 3 LSR. At Missoula, Mont., this variety was used as a check in a 12-variety, 6-replicate plot test. Percentages of Na and K were determined for this variety from all test plots at each factory location and the data analyzed statistically. Results as obtained for the different areas are given in Table 3.

Table 3.—Percentages of Sodium and Potassium in American 3 LSR at 5 factories (4 states)—1949.

Location	Na %	K %
Missoula	.044	.226
Rocky Ford	.147	.185
Mason City	.016	.227
Chaska	.023	.195
East Grand Forks	.101	.198
Significant difference (19:1)	.027	.028

The data obtained indicates very great variation in Na percents attributable to area of production. Lesser variation, but also significant, occurs in the K percent values. It is interesting to note that in the Mason City district the American 3 LSR variety, although extremely low in Na percent, is higher in K percent than in any of the other areas.

Variety Differences in Different Areas

It has been a general observation covering many years experience and testing that varieties often do not perform the same in different areas. Since a number of varieties were in replicated plot tests in several of the five factory district plot tests, it was possible to compare these varieties in more than one area in order to determine whether interaction between variety and area reached significance.

Three varieties, representing a wide range of *Cercospora* leaf spot resistance, were in test at both the Mason City and Chaska factory districts in 1949. At Stewart, Minn., (near Chaska) severe leaf spot occurred, while only a trace of leaf spot was found at Mason City. Performances of these varieties in each area with respect to yield, and sucrose, sodium and potassium percentages are given in Table 4.

The results of these tests show significant differences between varieties, and between areas, for all four characteristics. The only non-significant result in all the data is in sucrose percent at Stewart where only minor differences were obtained. F values computed in the analysis of variance for the variety

—area interaction were not significant for yield, sucrose, Na and K, indicating that the varieties performed similarly in both areas.

Table 4.—Comparison of tonnage yield, sucrose, sodium and potassium percentages of 3 varieties tested at Mason City, Ia., and Stewart, Minn.—1949.

Variety	Location	Tons Beets per Acre	% Sucrose	% Na	% K
7-401a	Mason City	16.9	18.6	.016	.231
7-401a	Stewart	11.7	16.8	.025	.187
Amer. 3 LSR	Mason City	18.2	17.6	.016	.227
Amer. 3 LSR	Stewart	14.0	16.5	.023	.195
3-428-0	Mason City	15.9	15.5	.032	.287
3-428-0	Stewart	11.8	16.0	.052	.207
(a) Significant Difference (odds 19:1)		2.20	1.04	.008	.029
Averages:	Mason City	17.0	17.2	.021	.248
	Stewart	14.8	16.5	.034	.196
(b) Significant Difference (odds 19:1)		1.27	.60	.005	.017
Averages:	7-401a	14.33	17.72	.021	.209
	Amer. 3 LSR	16.08	17.08	.020	.211
	3-428-0	13.87	15.73	.042	.247
(c) Significant Difference (odds 19:1)		1.55	.73	.006	.020

A second test of variety performance in different areas was possible in the plot tests of East Grand Forks and Missoula. Three varieties widely different in origin were used in this experiment. The results are given in Table 5.

Significant differences were obtained between varieties for yield, and for Na percents. Both areas produced similar yields, but significant differences between areas were obtained for sucrose, Na and K percents. Although variety performance was slightly different in each area it was not of high enough level to be satistically significant, and hence it can be assumed that the performance of the varieties was relatively the same in each area.

Table 5.—Comparison of tonnage yield, and of sucrose, sodium and potassium percentages of 3 varieties tested at Missoula, Mont., and East Grand Forks, Minn., in 1949.

Variety	Location	Tons Beets per Acre	% Sucrose	% Na	% K
7-801	Missoula	18.1	15.2	.053	.133
	East Grand Forks	19.0	15.9	.128	.248
U.S. 33	Missoula	12.9	15.4	.046	.137
	East Grand Forks	12.5	16.2	.107	.269
Amer. 3 LSR	Missoula	14.4	15.3	.044	.226
	East Grand Forks	16.0	16.3	.101	.198
(a) Significant Difference (odds 19:1)		2.5	.56	.025	.042
Averages:	Missoula	15.13	15.29	.047	.165
	East Grand Forks	15.86	16.11	.111	.238
Significant Difference (odds 19:1)		.....	.32	.014	.024
Averages:	7-801	18.57	15.55	.090	.190
	U. S. 33	12.72	15.76	.075	.203
	Amer. 3 LSR	15.20	15.79	.072	.212
Significant Difference (odds 19:1)		1.76	.....	.017	.....

Variations within Varieties

Since differences between varieties had been observed in several areas, attention was directed to differences between beets within varieties. For this study the Elite stock 7-401a was used. This variety had been subjected to a medium severe *Cercospora* leaf spot epidemic at Rocky Ford, Colorado,

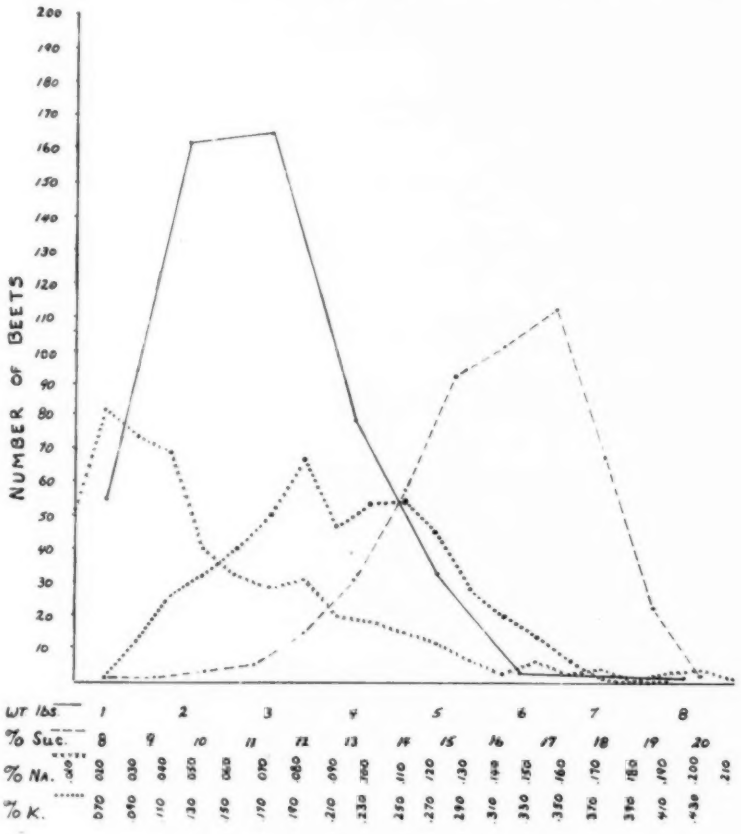

Figure 1. Frequency distributions for weight per beet, percent sucrose, percent sodium and percent potassium as determined from 500 beets of elite stock 7-401a.

and field selections of mother beets were made of those plants most resistant to the disease. Five hundred beets were used on which weights, together with sucrose, Na and K percentage data were obtained. Frequency distributions were set up for all four characters, as shown in Figure 1.

The frequency distributions obtained indicate that there were sizable differences between beets of this variety for percent Na and percent K. In Na, the range is from .010 to .210 percent; and in K the range is from .070 to .430 percent. As a result of these tests two groupings, each of 25 beets, were made for seed production as follows:

	Average			
	Weight, lbs.	% Sucrose	% Na	% K
Poorest	2.60	13.2	.107	.274
Best	3.88	17.8	.015	.140

A test of the progenies will be made to determine in 1950 what improvement can be made by the mass selection method of breeding.

Association of Na and K with Yield and Sucrose

In the improvement of sugar beet varieties it is important to know the degree of association between those characters being studied. Accordingly, correlation coefficients were calculated using yield, percent sucrose, percent Na and percent K in all possible pair combinations. Three sets of data were used: (a) 8-variety plot test (Table 2) analyzed by the co-variance method, (b) 500 beets of Elite Stock 7-401a selected at Rocky Ford and (c) 52 beets of American 5 selected at Clarksburg, California. Values of "r" with significance levels are given in Table 6.

Table 6.—Correlation coefficients (r) showing the relationship of weight, and of sucrose, Na and K in all possible pairs, as calculated from an 8 variety test, and individual roots of two varieties.

	Rocky Ford		Clarksburg
	8-variety Test	7-401a (500 Beets)	Amer. 5 (52 Beets)
Weight x Percent Sucrose	—.194	—.2596	—.2664
Weight x Percent Sodium	+.140	+.3160	+.2855
Weight x Percent Potassium	+.674	+.4457	+.1532
Percent Sucrose x Percent Sodium	—.731	—.7379	—.4296
Percent Sucrose x Percent Potassium	—.567	—.5312	+.0226
Percent Sodium x Percent Potassium	+.337	+.4662	+.1492
Significance level (19:1 odds)	.666	.088	.275

High yield and high Na and K content were positively associated in these tests. Sucrose percent was negatively associated with Na and K content. There was also a positive association of Na and K beyond the significant level in the data from 500 beets of the 7-401 a variety.

Summary

Preliminary to work on breeding for higher purity sugar beet varieties was a study of the technique necessary for accurate determination of sodium and potassium in beet samples by the spectrophotometer method. After a standard technique had been set up, pulp samples from varieties in one strip test and one 8 x 8 variety plot test were analyzed for sodium and potassium at Rocky Ford, Colo. One variety in pulp samples of field test in replicated plots in five areas was tested to determine area differences. Three varieties were tested in each of two factory areas to determine (a) variety, (b) area, and (c) variety-area differences, with respect to yield and sucrose as well as sodium and potassium.

Differences between beets of the same variety were determined on two varieties for yield, sucrose, sodium and potassium, and the relationships as measured by correlation coefficients determined for these distributions. An 8 x 8 variety plot test was given similar study. The results obtained indicate that major differences between varieties exist for sodium and potassium content as well as for yield and sucrose, and likewise, major differences exist in these characters between areas. Varieties performed similarly in different areas. It was also observed that domestic varieties generally were lower in sodium content than foreign check varieties included in the tests.

Tests of mother beets from two varieties indicated good possibilities for further improvement in sodium and potassium content because of the wide differences in amounts of these minerals found among the individual beets.

The relationships between yield and between sucrose, sodium and potassium percentages as measured by correlation coefficients indicate that sodium and potassium contents are associated to some degree with high yield, and are associated negatively with sucrose percent. Sodium and potassium percentages were associated positively in these tests.

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A Bolting Oddity in Sugar Beets

J. F. SWINK AND C. W. DOXTATOR[1]

Production of seed stalks in commercial sugar beet fields, commonly called "bolting," is a frequent occurrence in sugar beet-growing areas. Such plants commonly produce seed stalks only after the beet root has reached considerable size. If the season is long enough, normal flowering and seed production may follow.

An unusual type of bolter which produces a stalk directly after emergence of the seedling (Fig. 1) and which under field conditions produces no flowers, was first observed at Rocky Ford, Colorado, in 1944, in certain inbreds in the breeding nursery. This interesting oddity grows a very large stalk (see photograph) which at harvest date is approximately the diameter of the beet crown. Beets of 5 pound weight having a stalk diameter of 5 inches at the base and a height of 8 feet have been commonly found. Such beets cannot be topped by normal methods, and when topped as mother beets fail to produce any more growth. The upper portion of the beet as well as the crown is extremely fibrous. Obviously such beets are never selected for seed production.

Since 1944, selection in inbred and backcross progenies appears to have eliminated this character from the breeding nursery. Nevertheless, this nuisance character continues to reoccur in breeder's stock seed increases from groupings of inbreds and backcrosses originating from the hybrid seed lot in which this character was first observed.

Origin and Breeding History

In 1942 a cross was made of American 1 (M 35) with 0-419, a selection of U. S. 216, in one of the phases of the *Cercospora* leaf spot resistance breeding program. In the 1943-44 winter season roots of the hybrid and the parents were planted in the greenhouses for self-pollination and backcrossing to each parent. Twelve backcross seed lots were obtained and planted in the field in 1944, along with 25 self-pollinated progenies. Odd type bolters occurred in 10 of these progenies, both inbreds and backcrosses. All these progenies were discarded, along with several other progenies of which one of the parent roots had, in other crosses, produced odd type bolters.

In 1945 breeders' stock of some of these lines was obtained under the breeders' stock number 5-406; and on other lines backcrossing and selfing was continued. In 1946, 133 selfed and backcrossed progenies from these selections were planted in the nursery, none of which produced odd type

Figure 1. (See page 153) Here is shown an unusual type of bolter which produces a stalk directly after emergence of the seedling and which under field conditions produces no flowers. This interesting oddity grows a very large stalk (see bottom portion of Figure 1) which at harvest date is approximately the diameter of the beet crown. The upper portion of Figure 1 shows this unusual type of bolter directly after emergence of the seedling.

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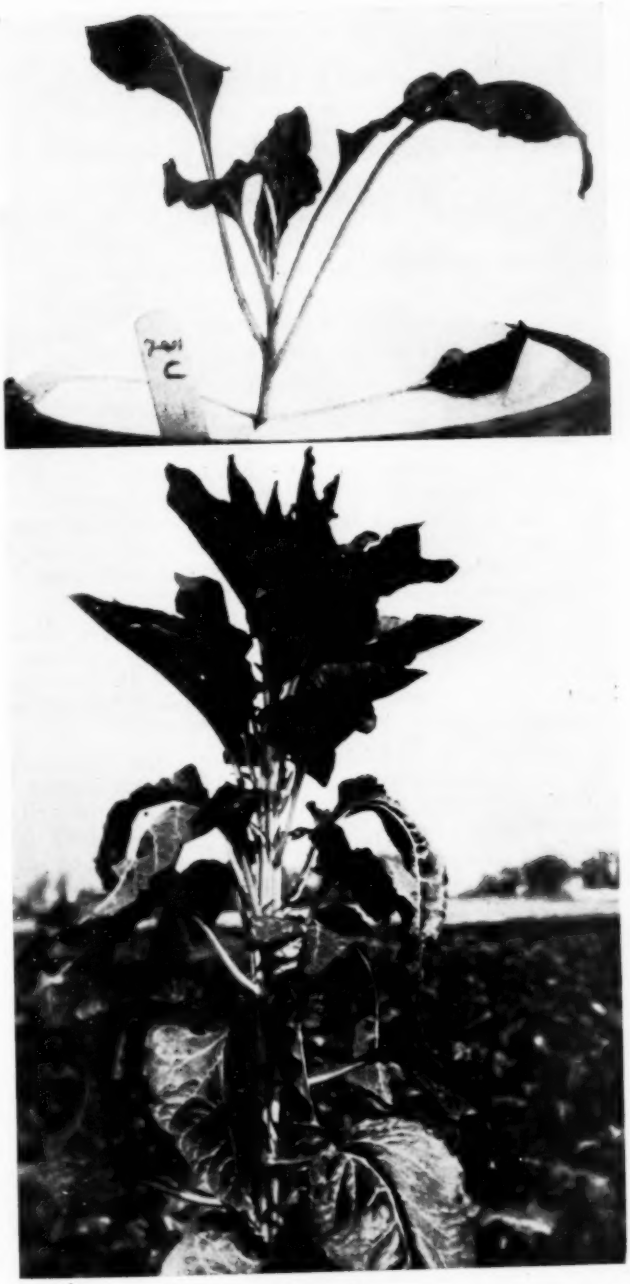

Figure 1.

bolters. The seed lot 5-406 was tested for yield in replicated plots, and was also free of bolters. In 1947 roots of 100 of the nursery progenies of 1946 were divided into three groups for seed increase in space isolation, as follows:

7-401 a : (35 x 0-419)35
7-401 b : (35 x 0-419)0-419
7-401 c : 35 x 0-419 selfs;

These three seed lots were tested in replicated plots in 1948 at Rocky Ford, Colorado, and were found to contain approximately .24% odd type bolting. No normal "quick" bolters were found in any of the 3 selections.

1948-1949 Experiments

Greenhouse planting of seed of 7-401a, b, and c, were made in 1948, for a further study of this character. Forty-three "odd" bolters were obtained from approximately 18,000 seedlings, distributed as follows:

7-401 a — 4 odd bolters
7-401 b — 6 odd bolters
7-401 c — 33 odd bolters

All of these odd bolting plants were left in flats for one month and then transplanted to 8" pots. Twenty-three of the plants were subjected to incandescent illumination during nights. The other twenty were allowed to grow without supplemental light.

After 5 weeks in the greenhouse the effect of incandescent supplemental light in promoting increased growth was evident. Seed stalks grew over 6 feet high and flowers were produced on several plants. However, all flowers were found to be male sterile. No plants under non-supplemental light conditions produced any flowers.

Since there were available in the greenhouse normal flowering beets of the 7-401a variety, several crosses were made by pollen transfer to odd bolting plants. Six seeds were obtained from one of these crosses. Two odd type bolters produced a few seeds from open pollination.

Plantings of these three seed lots in the spring of 1949 produced a total of 14 beets, all of which were normal non-bolting plants. Attempts are now being made to obtain self-pollinated seed from these plants for further study of the inheritance of this character.

Discussion

This odd bolting type as described, although occurring rather infrequently in variety test fields, is nevertheless a very serious character and must be eliminated before any sizable seed increase of this variety can be made. The character apparently is found only in certain crosses involving M-line number 35, since it has not been observed in any other of the many selections of American 1, nor in their hybrids.

Further studies of the inheritance of this character are being conducted from selected seedlings under incandescent supplemental light in the greenhouses.

Bolting In Annual Beets Induced by One-half Hour Supplemental Illumination During Long Winter Nights

G. K. RYSER, MYRON STOUT, AND F. V. OWEN[1]

Preliminary tests during short winter days with annual beets showed that reproductive development was induced effectively by interrupting the long dark period at 12:00 midnight with one-half-hour of light from a 150-watt reflector-type incandescent filament lamp hanging two feet above the beets. Seed-stalk development under conditions of interrupted dark periods, however, was somewhat slower than that induced by continuous illumination at night from the same source of light. Both groups of plants received normal sunlight during the daytime. This experiment with a long-day plant was suggested by experiments with photoperiodic control of floral initiation in barley. (H. A. Borthwick, S. B. Hendricks, and M. W. Parker. Action spectrum for photoperiodic control of floral initiation of a long-day plant, Wintex Barley (*Hordeum vulgare*). Botanical Gazette, 110:103-118. 1948.)

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[1] Collaborator, Physiologist and Senior Geneticist, respectively, Division of Sugar Plant Investigations of the Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

Monogerm Sugar Beets in the United States

V. F. SAVITSKY[1]

Monogerm sugar-beet varieties have not been developed in either Europe or America. Failure to develop such varieties is due to difficulties in detecting monogerm plants. Monogerm mutations are correlated with late-bolting ability and are ordinarily eliminated by natural selection. It is necessary to examine an enormous number of plants in different varieties to find monogerm races.

In 1948 an expedition to search for monogerm sugar beets was organized by the U. S. Department of Agriculture and the Curly Top Resistance Breeding committee with the assistance of the West Coast Beet Seed Company. In accordance with Dr. F. V. Owen's advice the plan involved two trips. I made the first trip in June to California and Oregon with Dr. Eubanks Carsner, Dr. J. S. McFarlane, Dr. R. A. Pendleton, Dr. H. Savitsky and Mr. Sam C. Campbell to choose seed-beet plantings with a wide choice of varieties and with the best opportunity for selection work. I made a second trip in July to Oregon for an intensive search for monogerm beets in selected fields just prior to the harvest period. I succeeded in finding five monogerm sugar-beet plants in the variety Michigan Hybrid-18 in a four-acre field with approximately 300,000 plants. This variety was the only variety in which I found true monogerm seed beets. I made a similar intensive search in Utah with Messrs. Myron Stout, C. H. Smith, Vernal Jensen and Dr. H. Savitsky in curly-top-resistant varieties, but it was unsuccessful. Plants having bilocular seed balls for the most part were found in all these varieties.

All five of the monogerm plants were late in floral development. More than half of their fruits were not ripe at the time of harvest. The selected plants were observed to be self-fertile during two generations. Approximately 75 percent of their progeny arose from selfing under open pollination. The selfed progenies consisted of very uniform monogerm plants which manifested considerable variation in time of bolting and flowering. F_1 hybrids between mono- and multigerm sugar beets were significantly more early bolting than the homozygous monogerm plants and produced variable F_2 progenies. F_1 progenies after selfing showed much greater variation in all characters than the progenies of selfed monogerm lines. Two of the five selections (races S.L.C. Monogerm 101 and 107) were very similar and it is evident that they originated from lines which had selfed for several generations. The other three selected races differed in characters of fruits, rosettes and seed beets.

The True Monogerm Sugar Beets

Only two of the five races, S.L.C. Monogerm 101 and 107, could be considered as true monogerm plants.

[1] Collaborator, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, in cooperation with the Curly Top Resistance Breeding committee.

1. The monogerm character appeared constant and not variable under different conditions, whether the plants grew at different times, in the greenhouse, or in the field.

2. The fruits were non-shattering, round and very uniform (Figure 1, upper picture).

3. Races 101 and 107 have a similar new type of branching new to the genus *Beta*: either a lateral branch or a single fruit can be borne in the axil of a leaf, but never both together. The monogerm plants can be recognized by this character in the early state of seed-stalk development.

4. The monogerm character and this peculiar type of branching are recessive.

5. Monogerm beets give ordinary sugar-beet-type seedlings.

6. Monogerm plants showed a strong non-bolting tendency.

Correlation Between Type of Fruits and Type of Branching and Leaf Development

The seed ball represents an inflorescence which later becomes a fruit. The type of inflorescence or fruit is caused by the type of branching which is apparently connected with the mode of leaf development. Therefore, selection of the new type of fruits led to the isolation of some new sugar-beet races with a new type of leaf development and branching.

I found some differences in seedlings in different *Beta* species. I observed in Salt Lake City during 1948 and 1949 that in the wild monogerm species *Beta lomatogona* the first true leaf developed 5-15 days earlier than the second (Figure 1, lower left). Branching in *B. lomatogona* differs from branching in the above-mentioned monogerm sugar-beet races because on the seed-stalk of *B. lomatogona*, besides a lateral branch, usually two monogerm fruits are borne in the axil of a leaf.

Development of one of the selected monogerm plants, N 100, resembles this *lomatogona*-type development. During two generations this line produced seedlings in which the first leaf appeared 3-10 days earlier than the second (Figure 1, lower right). The type of branching in plant N 100 is similar to that in *B. lomatogona*: in the axil of a leaf the branch and one or two fruits are usually borne. Race N 100 has not been studied sufficiently, but it evidently bears, besides monogerm fruits, also some double-germ fruits.

I observed the same variation of mono- and double-germ fruits in another selection, race N 27. The progeny of this plant showed a new inherited type of leaf development: the appearance of seedlings with three cotyledons.

Conclusions

Genetic study of different monogerm races is being conducted at present in Salt Lake City.

Knowledge of monogerm inheritance will clear up the causes which bring about modifications of type of fruits and will explain also why all these modifications arose in one variety.

Study of genetics will explain the cause of correlation between monogerm fruits and some other accompanying characters such as late-bolting tendency, new types of branching (races 101, 107) and leaf development (races 27 and 100).

Figure 1. The upper portion of this illustration shows the branches of monogerm race S.L. 101 with matured fruits.

The lower lefthand illustration in Figure 1 shows the first true leaf of the wild monogerm species *Beta Lomatogona* which developed five to fifteen days earlier than the second.

The lower right hand portion of the illustration pictures the development of one of the selected monogerm plants which resembles this *lomatogona* type of development. During two generations this line produced seedlings in which the first leaf appeared three to ten days earlier than the second.

Establishing the mode of inheritance of the monogerm character and recovering linked genes will facilitate the breeding of monogerm varieties. This is especially important in connection with the use of the backcross method.

The backcross method must be used on a large scale in breeding work with the monogerm character. Monogerm sugar beet varieties are needed by the whole country. Most of the valuable varieties in the U. S. A. are planted in their respective areas because of resistance to different diseases or because of other valuable biological properties. The monogerm character should be incorporated into all of these varieties in the near future. The easiest way to attain this objective is by the use of the backcross method.

Many problems arise in connection with self-fertility of monogerm beets. All sugar beet varieties tend to be self-sterile. Therefore, it is necessary to obtain self-sterile monogerm races and biologically different self-sterile populations. It is very interesting to obtain male-sterile monogerm beets and make use of F_1 hybrid vigor applying Dr. Owen's method. But in this case it is necessary to have heritably different monogerm pollinators.

A comprehensive breeding program has been initiated with progenies of races 101 and 107 at Salt Lake City and at Salinas, California. These monogerm beets have been crossed extensively with various curly-top-resistant varieties, including slow-bolting types of special interest for winter plantings in California. Late-bolting monogerm progenies were used also for the purpose of maintaining the extreme non-bolting tendency. Unless unexpected difficulties arise, this cooperative breeding program should result in a sufficient amount of elite monogerm seed for the initiation of commercial monogerm sugar-beet plantings in 1952-1953.

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Embryology of Mono- and Multigerm Fruits in the Genus Beta L.

HELEN SAVITSKY[1]

Embryology of multigerm seed balls was studied in *B. vulgaris L.* Development of monogerm fruits has been studied in all three sections: *Vulgares Tr., Corollinae Tr.* and *Patellares Tr.*

Beta Vulgaris, Multigerm Sugar Beet

Development of multigerm seed balls in *B. vulgaris* is as follows: The apex of the floral axis is built of meristematic tissue (Figure 1, upper left). The cells of this tissue are small and contain dense protoplasm. They are capable of rapid growth and cell division. Proportionally with the growth of the seedstalk, meristematic tissue of the apex produces new primordia of the bracts on the sides of the growing point. The edges of the apex of the meristematic tissue develop small primordia of flowers and seed balls in the axils of the bracts (Figure 1, upper right). The proturberances grow fast and differentiate the upper extended part, the receptacle, and a lower part, the peduncle (Figure 1, second from top, right). Each receptacle produces a flower.

The primordium of the second flower in the seed ball is formed before the protuberances of the sepals appear on the first receptacle, or at the time of their appearance. The edges of the meristem of the first receptacle come down covering the outside of the peduncle. Meristematic tissue forms a small swelling on the side of the peduncle at some distance from the first receptacle (Figure 1, third from top, right). This small swelling grows and turns into a protuberance and later into a new receptacle on the side of the same peduncle. Two, three and four such protuberances developing from these receptacles can be borne on a common peduncle and they correspond to the number of flowers in the seed ball (Figure 1, lower left). All flowers of the same seed ball develop simultaneously (Figure 1, lower right).

The bases of the ovaries of all flowers are imbedded in the tissue of the same peduncle (Figure 1, middle left). All flowers are joined by the tissue of the peduncle thus forming the seed ball, but the upper part of the buds, beginning from the base of the sepals, grows over the peduncle and gives the impression that each bud is developing separately. The individual flowers in the seed ball are borne together, but they do not grow together as is often assumed.

Figure 1. (See page 161) *Beta vulgaris* multigerm sugar beet: Upper left—apex of the floral axis x 300. Upper right—Primordium of the seed ball x 300. Center left—three matured buds in one seed ball x 20. Second from top, right—the receptacle and peduncle x 300. Third from top, right—beginning of development of second receptacle under first one x 300. Lower left—two receptacles on the common peduncle x 300. Lower right—two young buds developing in one seed ball x 68.

[1] Collaborator, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, in cooperation with the Curly Top Resistance Breeding committee.

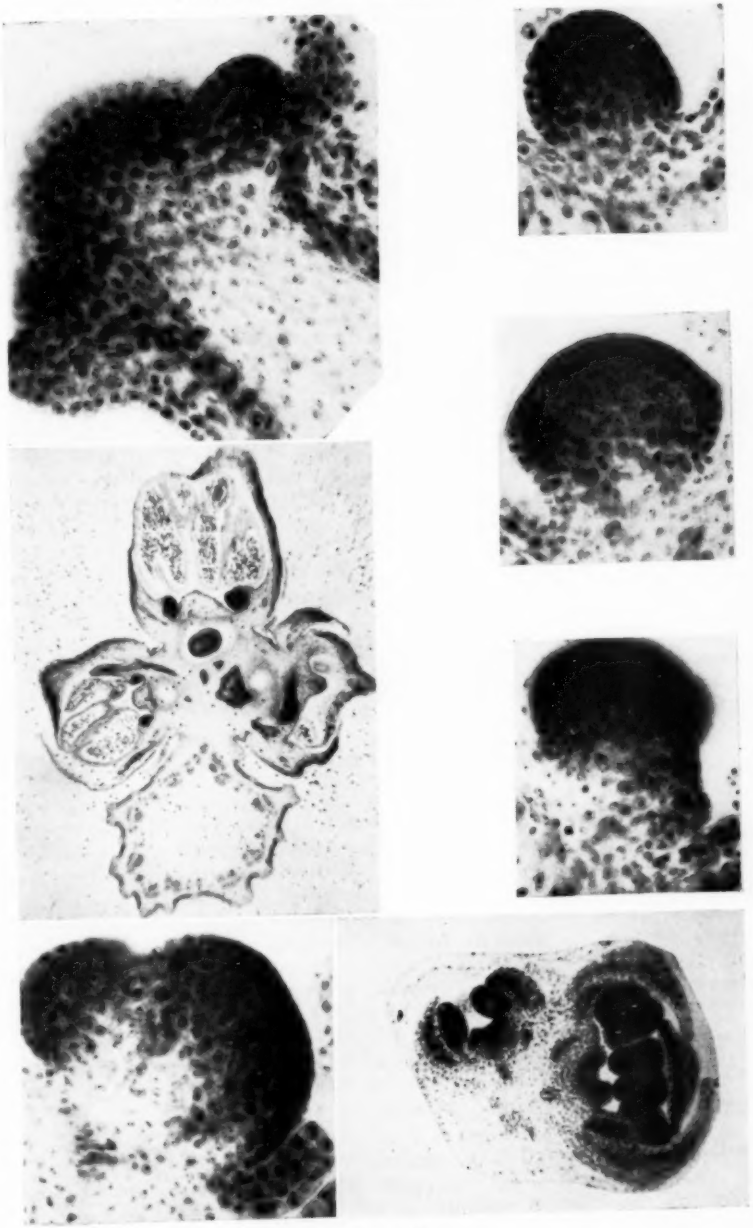

Figure 1.

Beta Vulgaris Monogerm Sugar Beet

In monogerm sugar beet plants the meristematic tissue of the apex of the floral axis produces also primordia of bracts, and small primordia of flowers in their axils. The protuberance of each flower in a short time forms a receptacle and a peduncle (Figure 2, upper left). The meristematic tissue of the receptacle does not come far down in monogerm beets and does not produce new receptacles. Only one receptacle develops on each peduncle; therefore, separate buds are always located in the axil of the bracts (Figure 2, middle top, and upper right). The formation of a flower involves the entire meristem of the receptacle. Monogerm races of *B. vulgaris* do not produce seed balls, they produce simple fruits. Each bud rests on a small peduncle. In monogerm plants the length of the peduncle is about one-third as long as in multigerm plants. Therefore, monogerm fruits shatter less than the seed balls in the majority of sugarbeet races.

Beta Lomatogona

The mode of production and development of the buds in *B. lomatogona* (Fisch and Mey) does not differ from the mode of development in the monogerm sugar beet. The primordia of the flowers are borne in the axils of the bracts. Additional receptacles and buds never develop on the same peduncle. Individual flowers grow in the axils of bracts of the floral axis in *B. lomatogona* (Figure 2, middle left). The length of the peduncle in the matured buds is the same as in monogerm sugar-beet plants, but the width of the peduncle in *B. lomatogona* differs from multi- and monogerm plants of *B. vulgaris*. Narrow peduncles are typical of *B. lomatogona* and cause comparatively easy shattering of the seeds (Figure 2, middle right). Like the monogerm sugar beet, *B. lomatogona* has simple fruits but not seed balls.

Beta patellaris and Beta procumbens

In spite of monogerm fruits in section *Patellares Tr.*, development of fruits in *B. patellaris* Moq. and *B. procumbens* Chr. Sm. follows the type of development of multigerm seed balls in sections Vulgares and Corollinae. Meristematic tissue of a protuberance produces several receptacles on the sides of the same peduncle (Figure 2, lower left). Each receptacle produces a single flower, but every flower develops its own pedicel. Thus, simple fruits but not seed balls are formed. The pedicels of all flowers in one inflorescence are joined at their base and form the umbel (Figure 2, lower right). The long and narrow pedicels in *B. patellaris* and *B. procumbens* cause the extremely easy shattering of fruits in these species.

Figure 2. (See page 163) Top row, *Beta vulgaris* monogerm sugar beet: Left—the receptacle and peduncle x 300. Center—the floral axis x 20. Right—developed bud in the axil of the bract x 68.

Center row, *Beta lomatogona:* Left—the floral axis x 20. Right—developed bud in the axil of the bract x 68.

Bottom row, *Beta patellaris:* Left—development of the second receptacle on the common peduncle x 300. Right—developed buds on the pedicels in one inflorescence x 68.

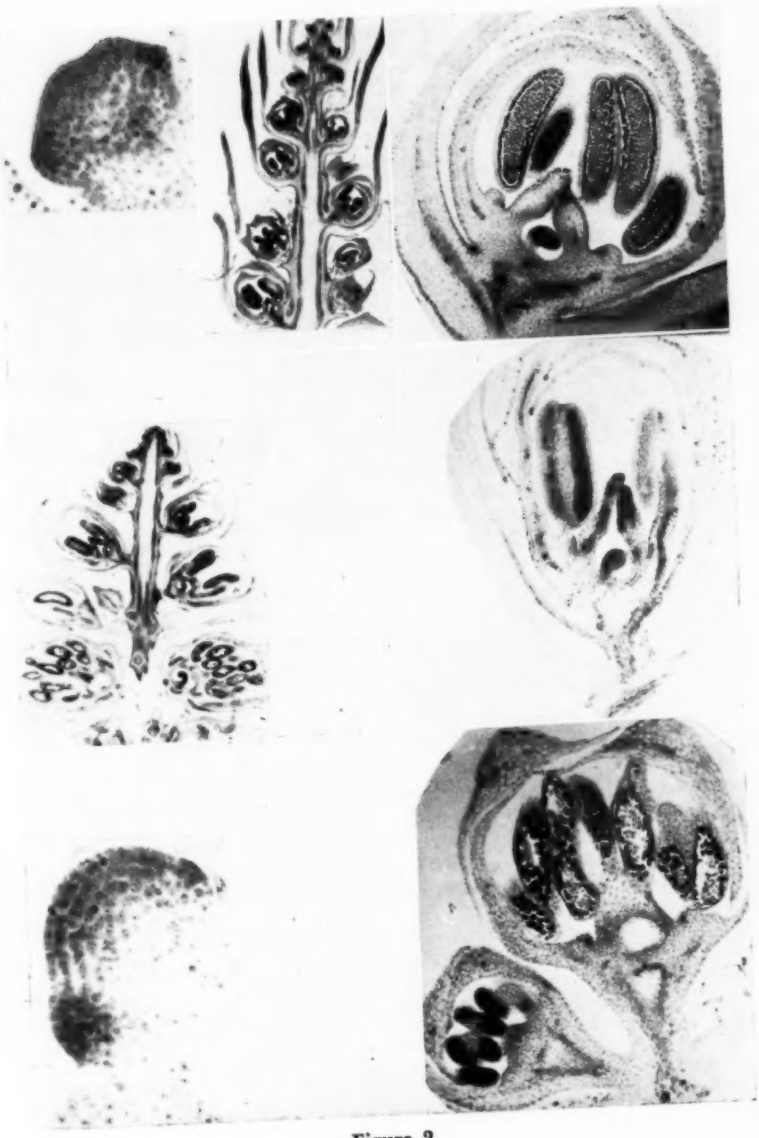

Figure 2.

Conclusions

The type of inflorescence in beets has been described as a spike, but the individual flowers and seed balls of beets do not grow directly on the floral axis, they are connected to the stem by peduncles or pedicels. Thus the inflorescence in all species of *Beta L.* is a panicle and not a spike.

The panicle bears simple fruits in *B. lomatogona* and monogerm sugar beets. In all sub-species and varieties of *B. vulgaris,* including ordinary sugar beets, the panicle bears multiple fruits or seed balls. As in all other species of section Corollinae (*B. trigyna,* Waldst and Kitt, *B. intermedia,* Bunge, etc.) the panicle bears seed balls. In *B. patellaris* and *B. procumbens* the panicle bears umbels.

Only in *B. lomatogona* and in monogerm races of *B. vulgaris* can it be considered that the fruits are truly monogerm in their origin. Therefore, only these two groups are valuable for the production of monogerm varieties.

A Genetic Study of 17 F_1 Hybrids And Their Inbred Parents[1]

H. L. KOHLS[2]

Greater improvement in sugar beets can be expected, in a given period of time, if our knowledge of the characteristics of the parent stocks can be used to predict, with reasonable accuracy, the characteristics of the F_1 plants. It may never be possible to predict which inbred lines will "nick" to produce a large amount of hybrid vigor but it may be possible to predict, with a fair degree of accuracy, such characteristics in the F_1 as percent sucrose, smoothness of root, and resistance to Cercospora leaf spot. If such predictions can be made, it will be a great time saver over the old trial and error method of developing hybrids.

A review of the literature adds very little to our knowledge of the subject. However, Stewart, Gaskill and Coons (7)[3] made a study of root yield, percent sucrose and yield of sugar in 35 hybrids and found relatively few hybrids exceeded significantly, in the attributes measured, the mean of the parents or a synthetic check. Other workers, (3), (4), (5), have reported hybrids with yield increases of 12 to 19 percent above good commercial varieties. Yield increases of more than 60 percent above inbred parent have been found but these same workers (8) also found hybrids which showed little or no increase over their parents. Snyder (9) states that crossed inbred lines may bring all the dominant genes together in the hybrid, if each inbred line carries the vigor factors which the other one lacks. Thus, all crosses between inbred strains do not result in the same degree of heterosis.

Savitsky (1) working with crosses involving sugar beets, mangels, Swiss chard and garden beets, is reported as giving evidence that 4 genetic factors are responsible for high sugar; one pair in Swiss chard and the other 3 in sugar beets. The work of Culbertson (2) with 3 F_1 crosses shows that the sugar percentage of the hybrids is about equal to the mean of the parents. He states that it is doubtful whether these are genetic factors which influence only sugar percentage. He and Pack (6) believe that many factors which influence morphologic characters of the plant may influence to a greater or less extent the sugar percentage of the beet. Culbertson (2) summarizes by saying that the ability to store sugar was found to be inherited in a quantitative manner and to be dependent upon the interaction of several genetic factors.

There seems to be no published information on the inheritance of resistance to Cercospora leaf spot and smoothness of root (lack of forking or sprangling) in sugar beets. Reference is made to crosses between sugar

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[2] Assistant Professor of Farm Crops, Michigan State College.

[3] The numbers in parentheses refer to literature cited.

and wild beets and the forked and sprangled type of root from such crosses. Apparently sprangled root type is partially dominant, if not completely so.

The purpose of this paper is to report the findings from comparisons of 17 F_1 hybrids with their inbred parents. These hybrids involve 17 inbred strains, 15 as male parents and 2 as male-sterile female parents. The small quantity of seed produced made it necessary to limit the test to one year, 1948. The method of developing the male-steriles and the field technique of testing the hybrids and their parents has been reported previously (4).

The hybrids significantly out-yield their lower yielding parent and most of them out-yield both parents (Table 1). A few are not significantly different from their higher yielding parent. One out-yields the standard variety. The yield of some of the hybrids is about equal to the combined yield of the two parents. It appears, from the data, that some of the male strains are similar to one or the other female line in their factors for yield, because the F_1 between them yields about the same as the higher yielding parent. Parents which produce hybrids which yield much more than either parent are probably quite different from each other in their yield factors. These data are in agreement with previous reports (3), (4), (5), (7), (8), and (9) and is what may be expected from common knowledge of other crops, such as corn.

The percent sugar of 4 hybrids is lower than their higher parents, but not significantly above the lower parent. There are 2 hybrids with percent sugar above the lower parent, but not significantly below the higher parent. The mean of the hybrids is about equal to the mean of the parents and not significantly different from either. The mean of the lower parents is different from the mean of the higher parents. These data agree with the work of Culbertson (2) and show that the sugar percentage of the hybrids is about equal to the mean of the parents.

Since sugar makes up a very large part of the total solids in sugar beets it is natural to expect the inheritance of the percent purity to be similar to the inheritance of sugar. In the data, presented here, there is a significant difference between the means of the parents. The mean of the hybrids is about midway between the parents. These data are similar to those for percent sugar and indicate that the inheritance of percent purity, probably, is the same as the inheritance of percent sugar, intermediate between the two parents.

Recoverable sugar is the product of tonnage, percent sugar and purity. The great influence of tonnage on recoverable sugar is shown in Table 2.

These data are very similar to the data for tonnage in Table 1. One hybrid is not significantly different from either of its parents in recoverable sugar. Two others are not above their higher parent. The mean of the lower parents is significantly different from the mean of the higher parents, and both are below the mean of the hybrids.

Inheritance of smoothness of root seems to follow the same pattern as percent sugar. The mean of the hybrids is about equal to the mean of

Table 1.—A comparison of hybrids with their inbred parents, for tonnage, percent sugar and percent purity of juice, expressed in terms of a standard variety as 1.00.

Male parent	Tonnage			Percent Sugar					
	Lower parent	Hybrid	Higher parent	Lower parent	Hybrid	Higher parent	Lower parent	Hybrid	Higher parent
Ac. 35 411802	.59 x	a .78	.70	.90	.93	.95 x	.99 x	.98	.99
Ac. 145 431901	.59 x	1.01	.87	.95 x	.98	1.00	.96	.99	.99 x
Ac. 297 624702	.39	aa .95 aa	.59 x	.95 x	.98 bb	1.06	.99 x	1.01	1.01
Ac. 310 851714	.43	aa 1.05 aa	.59 x	.95 x	1.00	1.02 x	.98	1.00	.99 x
Ac. 310 851909	.58	aa 1.08 aa	.59 x	.95 x	.91 bb	1.05	.99 x	.98	1.00
Ac. 312 620104	.59 x	aa 1.10 aa	.73	.91	.89	.95 x	.96	.95 bb	.99 x
Ac. 327 S.P.S. No. 1	.59 x	aa 1.07 a	.79	.95 x	.95 bb	1.07	.99 x	1.00	1.02
U. S. 200	.56 y	aa .85	.80	.96 y	aa 1.04	1.02	1.00 y	1.01	1.00
Ac. 32 57301	.56 y	aa .92 aa	.59	.95	.97	.96 y	.99	.99	1.00 y
Ac. 32 57305	.56 y	aa 1.19 aa	.57	.94	.94	.96 y	1.00 y	.99	1.01
Ac. 35 410602	.56 y	aa 1.06 aa	.81	.94	.94	.96 y	1.00 y	1.00	1.00
Ac. 35 411802	.56 y	aa 1.11 aa	.60	.96 y	.96	.96	1.00 y	1.01	1.02
Ac. 40 416003	.56 y	aa 1.02 aa	.66	.96 y	.94	.98	1.00 y	1.00	1.00
Ac. 60 420104	.56 y	aa .97 aa	.61	.96 y	.92 b	.98	1.00 y	.98	1.00
Ac. 265 433603	.56 y	aa 1.01	.84	.94	.99	.96 y	.98	.99	1.00 y
Ac. 297 624702	.26	aa .92 aa	.56 y	.96 y	aa 1.04	1.06	1.00 y	.98 b	1.02
Ac. 312 620102	.36	aa .71	.56 y	.96 y	.96	1.02	1.00 y	.99	1.01
Average	.45±.06	.99±.06	.69±.06	.94±.02	.96±.02	1.01±.02	.98±.01	.99±.01	1.01±.01
L. S. D.	.18 5% .24 1%			.06 5% .08 1%		.03 5% .04 1%			

a —hybrid significantly above the parent at the 5% level.
aa—hybrid significantly above the parent at the 1% level.
b —hybrid significantly below the parent at the 5% level.
bb—hybrid significantly below the parent at the 1% level.
x —female parent, Ac. 32 57301
y —female parent, Ac. 35 410603

Table 2.—A comparison of hybrids with their inbred parents, for recoverable sugar per acre, smoothness of roots and resistance to Cercospora leaf spot, expressed in terms of a standard variety as 1.00.

Male parent	Recoverable sugar			Smoothness of root			Leaf Spot resistance		
	Lower parent	Hybrid	Higher parent	Lower parent	Hybrid	Higher parent	Lower parent	Hybrid	Higher parent
Ac. 35 411802	.57 x	.69	.61	1.01 x	1.03	1.01	.84	.85 bb	.99 x
Ac. 145 431901	.57 x	aa .98	.83	1.01 x	1.01 bb	1.08	.80	aa .87 bb	.99 x
Ac. 297 624702	.40	aa .94 aa	.57 x	1.01 x	aa 1.10	1.14	.86	.85 bb	.99 x
Ac. 310 851714	.42	aa 1.05 aa	.57 x	1.01 x	aa 1.07	1.09	.91	bb .85 bb	.99 x
Ac. 310 851909	.57 x	aa .97 aa	.61	1.00	1.00	1.01 x	.92	b .89 bb	.99 x
Ac. 312 620104	.57 x	aa .95 aa	.68	.99	1.00	1.01 x	.93	bb .86 bb	.99 x
Ac. 327 S.P.S. No. 1	.57 x	aa 1.02 aa	.87	1.01	1.00	1.02	.99 x	.97 bb	1.04
U. S. 200	.51 y	aa .90	.81	.95 y	aa 1.01	1.01	.98 y	.98	.98
Ac. 32 57301	.51 y	aa .89 aa	.57	.95 y	.98	1.01	.98 y	1.00	.99
Ac. 32 57305	.51 y	aa 1.10 aa	.53	.95 y	.98 b	1.02	.98 y	.99 bb	1.03
Ac. 35 410602	.51 y	aa 1.00 aa	.75	.95 y	.98	.99	.90	aa .95 b	.98 y
Ac. 35 411802	.51 y	aa 1.09 aa	.59	.95 y	a 1.00 b	1.04	.84	a .87 bb	.98 y
Ac. 40 416003	.51 y	aa .95 aa	.65	.95 y	a 1.00	1.02	.98 y	.97 b	1.00
Ac. 60 420104	.51 y	aa .88	.60	.95 y	.99	1.02	.96	bb .90 bb	.98 y
Ac. 265 433603	.51 y	aa .99 aa	.77	.95 y	.99 bb	1.05	.87	a .89 bb	.98 y
Ac. 297 624702	.27	aa .51 y	.51 y	.95 y	aa 1.02 b	1.07	.83	aa .89 bb	.98 y
Ac. 312 620102	.36	a .66 aa	.51 y	.95 y	a 1.00 b	1.06	.90	bb .85 bb	.98 y
Average	.42±.06	.94±.06	.66±.06	.99±.02	1.01±.02	1.04±.01	.90±.01	.91±.01	1.00±.01
L. S. D.		.18 5% .24 1%			.05 5% .06 1%			.03 5% .04 1%	

a —hybrid significantly above the parent at the 5% level.
aa—hybrid significantly above the parent at the 1% level.
b —hybrid significantly below the parent at the 5% level.
bb—hybrid significantly below the parent at the 1% level.
x —female parent, Ac. 32 57301
y —female parent, Ac. 35 410603

the parents (Table 2), and suggests that many factors which influence morphologic characters of the plant may also influence the smoothness of the root.

Resistance to Cercospora leaf spot seems to be inherited in a manner different from the characters discussed previously. There are only 2 hybrids which are not significantly different from their higher parent, all the others being below the higher and more resistant parent. Five are above, 5 below and 7 are about equal to the lower parent. The mean of the lower parents and the mean of the hybrids are not significantly different, but both are below the mean of the higher parents. It appears, from these data, that the hybrids are usually more like the susceptible parent, and a few may be even more susceptible than either parent. In 2 cases the lower parent, higher parent and hybrid are not significantly different from each other.

The data show that the yielding ability of the F_1 hybrids can not be predicted from our knowledge of the yielding ability of the parent stocks. Percentage of sugar and purity and smoothness of root are about intermediate between the two parents and can be predicted fairly accurately. Resistance to Cercospora leaf spot can be predicted only to the extent that the F_1 usually is more like the less resistant parent.

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Evaluation Tests in 1949 of Hybrid 125[1]

H. L. KOHLS[2]

This is a report of the second year of evaluation tests[3] involving hybrid 125, a hybrid developed by the use of cytoplasmically-inherited male-sterility[4].

Table 1.—Data from 13 variety tests in the eastern sugar beet area in 1949.

Location	Variety	Tons per acre	Percent sugar	Percent purity	Sugar per acre
Paulding, Ohio	H. 125	21.91 [a]	15.59	85.05	5.811 [a]
	215 x 216	17.86	15.17	84.16	4.553
Paulding, Ohio	H. 125	22.59 [a]	15.46	85.09	5.933 [a]
	216 x 225	20.29	15.23	83.93	5.189
Blissfield, Mich.	H. 125	14.59	15.57 [a]	89.16	4.067 [a]
	215 x 216	13.84	14.78	86.92	3.574
East Lansing, Mich.	H. 125	15.90	13.90	79.50	3.520
	Muck variety	12.50	17.00	86.40	3.677
Merrill, Mich.	H. 125	26.38 [a]	16.88	88.74	7.905 [a]
	215 x 216	19.67	17.36	90.24	6.167
Saginaw, Mich.	H. 125	11.87	19.34	89.16	4.072
	216 x 225	11.54	19.01	90.13	3.965
Reese, Mich.	H. 125	17.83	18.19	87.01	5.670
	215 x 216	18.55	18.11	86.42	5.810
Reese, Mich.	H. 125	15.87	16.19	85.64	4.416
	215 x 216	15.68	16.34	85.25	4.404
Mason City, Iowa	H. 125	11.44	19.09	.....	4.357
	Amer. Cry. No. 3	11.17	19.09	.....	4.265
Stewart, Minn.	H. 125	17.03 [a]	17.81	.....	6.070 [a]
	Amer. Cry. No. 3	14.73	18.08	.....	5.330
Chatham, Canada	H. 125	19.17	17.16	.....	6.576
	215 x 216	16.84	17.01	.....	5.735
Wallaceburg, Canada	H. 125	13.64	16.81	.....	4.588
	215 x 216	13.89	16.45	.....	4.571
Quebec, Canada	H. 125	13.71	13.00	82.90	3.565
	215 x 216	12.05	13.40	83.30	3.229
Average	H. 125	17.07	16.54	85.81	5.120
	Standard	15.28	16.69	86.31	4.651
Difference		1.79	.15	.50	469

[a] Hybrid is significantly above the standard variety.

[1] Contribution from the Farm Crops Section, Michigan Agricultural Experiment Station, East Lansing, Michigan. Authorized for publication by the Director as Journal article No. 1143 of the Michigan Agricultural Experiment Station.

[2] Assistant Professor of Farm Crops, Michigan State College.

[3] Cooperators in conducting these tests include G. H. Coons, J. G. Lill, Dewey Stewart, J. O. Gaskill, J. A. Elder, G. W. Deming, J. P. Kintzley, H. W. Bockstahler and C. L. Schneider, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture; Perc A. Reeve and Grant Nichol, Farmers and Manufacturers Beet Sugar Association; J. F. Davis, Soils Science Department, Michigan State College; H. H. Heilman, Great Lakes Sugar Company; B. E. Easton, Canada and Dominion Sugar Company; Clare Irvin, Lake Shore Sugar Company; C. W. Doxtator, American Crystal Company; H. E. Brewbaker and H. L. Bush, the Great Western Sugar Company; C. E. Cormany and Donald F. Peterson, Holly Sugar Corporation; and F. Dimmock, Central Experimental Farm, Canadian Department of Agriculture.

[4] Summary of the 1948 Evaluation Tests of Sugar Beet Varieties Developed in Michigan. Kohls, H. L. Proceedings of the American Society Sugar Beet Technologists. Fifth Regional Meeting, Detroit, Michigan. 1948.

Data from 25 locations, 13 in the eastern and 12 in the eastern slope area, are shown in Tables 1 and 2.

In the eastern area, Table 1, hybrid 125 has an average of 1.79 tons per acre and 469 pounds of sugar per acre more than the commercial variety commonly grown. This is an increase of 12 percent in tonnage and 10 percent in sugar per acre. These percentages are very close to those reported for 1948. Hybrid 125 shows no advantage over the commercial variety at Reese and East Lansing (on muck soil) in recoverable sugar per acre, which confirms the data a year ago at these two locations.

Table 2.—Data from 12 variety tests in the eastern slope sugar beet area in 1949.

Location	Variety	Tons per acre	Percent sugar	Total sugar per acre
Ault, Colo.	H. 125	21.28	17.58	7,496
	Local	21.75	17.88	7,778
Eaton, Colo.	H. 125	24.95	16.50	8,009
	G. W. 59	24.27	15.99	7,979
Fort Collins, Colo.	H. 125	15.18	15.76	4,785
	G. W. 59	15.85	15.51	4,917
Fort Collins, Colo.	H. 125	18.70 [b]	13.99 [b]	5,243 [b]
	Local	20.79	15.20	6,332
Fort Collins, Colo.	H. 125	23.39	16.96 [b]	7,931 [b]
	Local	23.83	17.71	8,425
Fort Morgan, Colo.	H. 125	25.64	15.97	8,189
	G. W. 59	25.89	15.07	7,803
Longmont, Colo.	H. 125	27.46	14.86	8,161
	G. W. 59	28.21	14.74	8,316
Rocky Ford, Colo.	H. 125	24.97	14.01 [b]	7,480
	Amer. Cry. No. 1	25.46	14.69	7,015
Gering, Neb.	H. 125	20.66 [a]	16.85	6,982 [a]
	G. W. 59	18.67	16.65	6,217
No. Platte, Neb.	H. 125	25.81	13.61	7,025
	G. W. —	25.56	13.46	6,881
Scottsbluff, Neb.	H. 125	20.25	16.10 [a]	6,521 [a]
	G. W. 59	19.55	15.21	5,947
Torrington, Wyo.	H. 125	22.72	13.59	6,217
	40249-0	23.84	14.07	6,707
Average	H. 125	22.58	15.48	7,002
	Standard	22.81	15.52	7,026
Difference		.23	.04	24

[a] Significantly above the standard variety.
[b] Significantly below the standard variety.

In the eastern slope area, Table 2, hybrid 125 shows no advantage over the commercial varieties in most of the tests. Scottsbluff and Gering, Nebraska, are the two exceptions where it has a definite advantage over the standard variety.

In summary, tests in 25 locations show that hybrid 125 is well adapted in the eastern area. No serious defects are apparent and in some localities in this area it outyields significantly the commercial variety.

Hybrid Combinations Among Mother Line Progenies

D. F. PETERSON AND C. E. CORMANY[1]

Local adaptation is an important factor to be considered in securing maximum production in a given area. Mass selection has been commonly used to obtain adaptation but this method has very definite limitations. A more intense method of selection should push production to a level above that obtained by mass selection. One such method is the testing of progenies of individual plants. The best progenies are grouped for a seed increase of a new superior variety. Doxtator[2] improved upon this method by making and testing all possible single crosses among the selected lines. From this information, lines which perform poorly in hybrid combination may be discarded. The results of such a procedure are reported in this paper.

Materials and Methods

In 1946 a group of 130 roots of Holly 13, breeder's stock of commercial seed for the Sheridan-Hardin area, were selected at Sheridan, Wyoming. These roots were stored in the root cellar, analyzed for sucrose, and reduced to a group of 56 roots on a weight-sucrose basis. Seed was harvested individually from 31 of these plants in 1947. In 1948, 17 plants which produced the most seed, along with two checks, were tested in a randomized block of five replications. Plots were 2 rows by 25 feet long. Remnant seed of each of the 17 lines was planted in selection blocks.

Significant differences were obtained in the test. Six of the 17 lines tested produced more sugar per acre than the check and, except for 2 lines, showed increases over the check in both sucrose and tonnage. Approximately 250 roots of each of these 6 lines were taken from the selection blocks and stored in the root cellar for use in making hybrid combinations. After a storage period of 67 days, 50 roots of each line were set out in 8-inch pots in the greenhouse. Temperatures between 50° and 60° F. were maintained until flowering, and supplemental light was used during the night. Branches were bagged with No. 14 paper bags just prior to flowering. Bag switching technique, as described by Doxtator[2], was used in making the crosses. Forty crosses (including reciprocals) of each of the 15 crosses, as well as each of the sibbed lines were made. Seed was harvested on May 3. Sufficient seed of all hybrids and sibbed lines was produced to plant a yield test of 6 replications, with plots 2 rows x 25 feet in size. The test was planted May 10, 1949.

Results and Discussion

The 1948 test performance of the 6 selected mother lines, together with the check variety from which they were selected, is given in Table 1.

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[1] Plant Breeder and Chief Agronomist respectively, Holly Sugar Corporation.
[2] Some Crossing Experiments with Sugar Beets, C. W. Doxtator and A. W. Skuderna, Proc. Amer. Soc. Sugar Beet Tech., 1942.

Table 1.—Production of 6 selected mother lines and variety check, 1948 data, Sheridan, Wyo.

Line	Acre Yield		Sucrose	Beets per 100' row
	S/A	Tons		
705-4	5,973	16.537	18.05	114
705-14	5,617	15.465	18.16	105
705-22	6,461	18.646	17.80	111
705-26	5,646	15.337	18.41	108
705-31	5,783	16.144	17.92	97
705-32	5,927	16.696	17.76	98
Holly 13	5,569	15.796	17.64	97
LSD (19:1)	611	1.673	.58	16

The 6 lines were selected for superiority in production of sugar per acre. Greater emphasis was placed on sucrose content than tonnage in selecting the lines.

Table 2 presents the 1949 test results. In this table the production of the 6 sibbed lines, all possible hybrids among the 6 lines, and the variety check are given.

Table 2.—Acre production of 6 sibbed mother lines, all possible hybrid combinations, and variety check, Sheridan, Wyoming, 1949.

	% Sucrose						
	Sibbed	705-4	705-14	705-22	705-26	705-31	705-32
705-4	17.25	.....	17.36	17.26	17.50	17.14	17.24
705-14	17.62		.....	17.20	17.88	17.59	17.36
705-22	16.70			.....	17.27	17.17	16.98
705-26	17.70				.....	17.46	17.59
705-31	17.16					.....	17.02
705-32	17.34						.....
Holly 13	16.76	LSD (5%) : .37					

	Tons/Acre						
	Sibbed	705-4	705-14	705-22	705-26	705-31	705-32
705-4	12.810	.....	15.088	18.610	15.362	17.918	15.389
705-14	14.259		.....	17.233	14.535	15.734	15.815
705-22	16.528			.....	16.840	15.444	17.568
705-26	13.039				.....	14.371	14.145
705-31	13.692					.....	15.519
705-32	13.189						.....
Holly 13	14.473	LSD (5%) : 1.878					

	S/A						
	Sibbed	705-4	705-14	705-22	705-26	705-31	705-32
705-4	4,424	.....	5,242	6,423	5,368	6,136	5,308
705-14	5,020		.....	5,933	5,188	5,534	5,491
705-22	5,524			.....	5,817	5,302	5,965
705-26	4,620				.....	5,020	4,974
705-31	4,700					.....	5,281
705-32	4,569						.....
Holly 13	4,856	LSD ((5%) : 665					

The average production in sugar per acre of the 6 mother lines was nearly the same as the parent variety. However, the 15 hybrids among the 6 lines exceeded both parents in production except for one case. Four hybrids significantly exceeded both parents and 7 hybrids significantly exceeded one parent.

In percent sucrose the 6 mother lines averaged .54 percent above the parent variety, reflecting the emphasis placed on sucrose at the time the mother lines were selected. No hybrid vigor was evidenced in any of the hybrids in percent sucrose.

The 6 mother lines yielded slightly less than the parent variety in tons per acre but the average yield of all 15 hybrids was significantly greater than the parent variety. Here again all hybrids except one exceeded both parents.

A synthetic variety using all 6 of these lines should show a theoretical 11.44 percent increase in production over the parent variety from which these lines were selected.

Conclusions

Better than average mother lines produced hybrid combinations which were significantly better sugar producers than the parent line. A judicious choice of the mother lines to be used in forming a new variety, considering the possible hybrids among those lines, will produce a better variety than had the various possible hybrid combinations not been taken into consideration.

Sugar Beet X Beta Procumbens, the F_1 and Backcross Generations

DEWEY STEWART[1]

The sugar beet (*Beta vulgaris* L.) and the three species of the section *Procumbentes*[2] hybridize readily, but the F_1 seedlings usually do not live beyond the second or third leaf stage. Hundreds of F_1 seedlings have been obtained from the hybridizations in which sugar beets of various varieties have been used as maternal parents and either *B. procumbens* Chr. Sm., *B. patellaris* Moq., or *B. webbiana* Moq., occurred as the pollen parent.

Figure 1. Two seedlings of the same age. Left, healthy sugar beet; Right, unthrifty F_1 sugar beet x *B. procumbens*. The F_1 seedlings seldom survive beyond the stage shown here.

Each of these wild species when mated with the sugar beet has given the same type of unthrifty F_1 plants, which seldom survived beyond the seedling stage. A typical F_1 seedling is shown on the right in Figure 1. However, in one of the hybrid progenies of sugar beet x *B. procumbens*, a seedling became fairly vigorous after three or four weeks of laggard growth and eventually produced several flowering branches. This plant is shown in Figure 2.

The F_1 plant was pollen sterile but approximately 45 seeds were produced following heavy applications of sugar beet pollen. The seeds as shown in Figure 3 were monogerm and in this respect the hybrid resembled somewhat the *B. procumbens* parent. There was a tendency for two or three seeds to adhere in clusters but these could be broken apart easily.

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[1] Senior Agronomist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

[2] Coons, G. H. "Wild species of genus *Beta*"—1938 Proc. Amer. Soc. Sugar Beet Tech., pp. 74-76.

Figure 2. Left, F_1 plant, sugar beet x *B. procumbens* at flowering stage. Right, *B. procumbens.*

Figure 3. Left, sugar beet seed; Center, seeds produced on F_1 plant, sugar beet x *B. procumbens;* Right, monogerm seeds of *B. procumbens.*

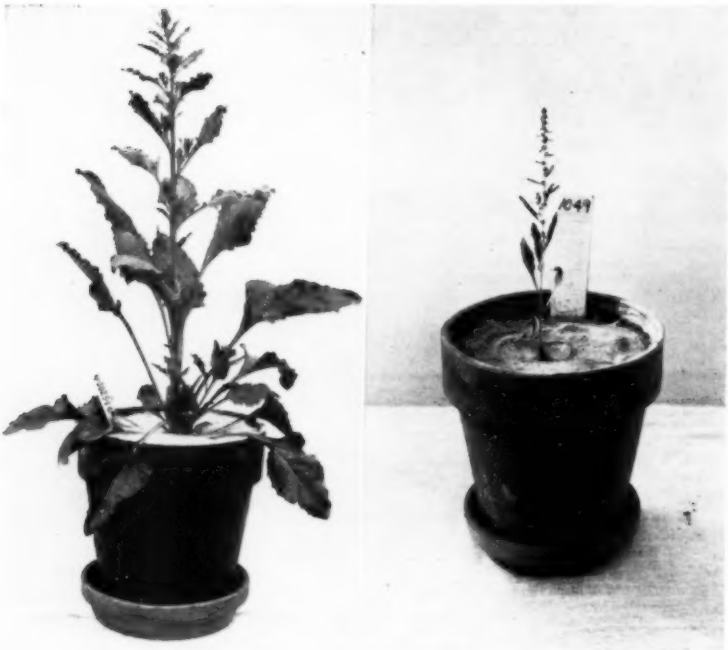

Figure 4. Left, plant of the first backcross generation (sugar beet x *B. procumbens)* x sugar beet. This plant produced a few seed. Right, plant of second backcross generation. Seed parent shown on left.

A progeny of 26 seedlings was obtained from the seeds produced on the F_1 plant. Unfortunately, the seedlings arising from the backcross showed the same unhealthy condition as that observed in the F_1 and except for two plants the entire progeny was lost. The two survivors grew to sexual maturity. They were pollen sterile, as was true of their F_1 mother. One of these plants, shown in Figure 4, set a few seeds when pollinated with sugar beet pollen.

Only two seedlings, representing the second backcross generation, were obtained from the seeds produced on the plant shown in Figure 4 (left). One died in the seedling stage and the other one, though not a vigorous plant, produced a seed stalk about one foot in length. This plant, shown in Figure 4 (right), grew to the flowering stage but died without forming a seed, thereby bringing to a disappointing end the series of hybridizations.

Schneider[3] has reported sugar beet x *B. procumbens* hybrids which behave quite differently from the ones described here. He stated that there

[3] Schneider, F. Zuechtung der Betarueben *in* Roemer, T. Handbuch der Pflanzenzuechtung 4(4):1-92. 1939.

was an F_2 with certain segregations of which it is impossible to get a clear idea. All generations are completely fertile. Coons has questioned whether the material studied by Schneider was hybrid, since the criterion used in picking out the F_1 was a slight delay in germination of a portion of the seed[4]. The cultures he saw were entirely like *Beta vulgaris* in growth habit.

Beta procumbens and its allies may contribute some important genetic characters. Two German investigators, according to Schneider, have reported that the species is either not attacked by the sugar beet nematode or that the larvae which penetrate the roots do not form cysts. The species shows immunity or near immunity to certain sugar beet diseases. Whereas a high degree of leaf-spot-resistance has been established by selection and breeding within the commercial varieties of sugar beet, actual immunity to the pathogen has been found only in *B. procumbens* and other species of the section *Procumbentes*. Similarly, there is evidence of high resistance if not immunity to the curly top virus. In addition to these characters, all three species of this section of the genus *Beta* have truly monogerm seed, a character much desired in the sugar beet as an aid in mechanizing the operations in growing the crop. It is recognized that these species are characterized by a fibrous root system, and a viny, indeterminate growth habit, clearly undesirable characters from the standpoint of sugar beet production.

The difficulties presented by lack of viability and fertility in the hybrids when these wild species are mated with sugar beet are not solved. The limited success obtained in the hybridization here reported is encouraging for additional and more extensive attempts.

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[4] Verbal communication from G. H. Coons who saw Schneider's cultures in 1935.

Recent Results with Sugar X Red Garden Beet Hybrids[1]

G. W. DEMING[2]

Two white F_3 hybrid beet varieties have been produced from crosses of sugar beet x red, globe garden beet. Several advanced generations of these hybrid varieties have been produced by both continuous selection and by random increases from the original F_3 seed stocks; one of the varieties having been advanced to the F_8 and F_7, respectively.

Table 1.—Yield of roots in tons per acre of sugar beet x red, globe garden beet hybrid varieties and a commercial sugar beet check variety. Data given as 6-plot averages.

Seed No.	Generation	Fort Collins, Colo., tests				Ault, Colo., tests	
		1939	1943	1945	1949	1948	1949
(First hybrid)							
1935—520	Sel. 3rd	14.45	15.78	14.84	21.94	13.30	24.05
1937—304	Sel. 4th	14.64	15.24	14.16	21.02	.....	.....
1939—303	Sel. 5th	.....	15.60	15.17	22.15	.....	.....
1939—300	Sel. 5th	.....	16.08	.....	21.45	.....	.....
1942—309	Sel. 6th	.....	15.90	15.47	22.38	.....	.....
1944—306	Sel. 7th	.....	.....	14.12	22.06	13.49	23.77
1946—311	Sel. 8th	.....	.....	.....	22.08	.....	24.60
1938—301	Rand. 4th	12.61	15.89	15.10	22.78	.....	.....
1942—305	Rand. 5th	.....	16.56	13.73	22.36	.....	.....
1944—305	Rand. 6th	.....	.....	13.56	22.50	.....	.....
1946—312	Rand. 7th	.....	.....	.....	20.82	13.19	23.47
1938—302	Rand. 5th[2]	13.60	15.27	.....	20.35	.....	.....
1938—300	Sel. 4th	13.98	16.17	.....	21.85	.....	.....
(Second hybrid)							
1940—312	2nd	.....	.....	.....	.....	.....	25.80
1942—306	Sel. 3rd	.....	18.86	16.23	.....	14.69	26.74
1945—312	Sel. 4th	.....	.....	.....	.....	14.51	26.05
1945—315	Rand. 4th	.....	.....	.....	.....	15.60	25.42
1948—312	Sel. 5th[2]	.....	.....	.....	.....	.....	24.16
Local commercial check		13.74	15.24	14.14	20.82	12.50	22.17
U. S. No. 226		.....	.....	.....	19.52	.....	.....
Two times the Standard Error of a Difference		1.87	1.48	1.36	1.74	1.01	1.83

[1] Random increase of selected 4th (1937-304)
[2] Selected for high sucrose with size of root given minor consideration.
Note: 1948 test at Ault, Colo., defoliated by hail July 30.

Yield trials of the hybrid varieties in comparison with a commercial sugar beet variety and their respective advanced generations, as the latter became available, have been conducted from time to time and at various locations since 1936.

[1] Conducted in cooperation with the Colorado A & M Agricultural Experiment Station.
[2] Agronomist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

The selected F_3 hybrid varieties and their advanced generations have in general exceeded the commercial sugar beet check variety in yields of roots; have had slightly lower percentage sucrose and have seldom differed significantly from the commercial variety in yields of gross sugar.

When the advanced generations are compared among themselves and with the original F_3 hybrid variety the differences in yields and quality are generally well within the limits of probable error. While a few instances

Table 2.—Percentage sucrose of sugar beet x red, globe garden beet hybrid varieties and a commercial sugar beet check variety. Data given as six plot averages.

Seed No.	Generation	Fort Collins, Colo., tests				Ault, Colo., tests	
		1939	1943	1945	1949	1948	1949
(First hybrid)							
1935—520	Sel. 3rd	15.96	15.13	13.32	16.14	11.72	17.24
1937—304	Sel. 4th	16.27	14.91	13.42	15.79	.....	.....
1939—303	Sel. 5th	.....	14.92	13.96	15.66	.....	.....
1939—300	Sel. 5th	.....	15.25	.....	15.61	.....	.....
1942—309	Sel. 6th	.....	15.42	13.76	15.71	.....	.....
1944—306	Sel. 7th	.....	.....	13.92	15.83	11.74	17.61
1946—311	Sel. 8th	.....	.....	.....	16.20	.....	17.97
1938—301	Rand. 4th	15.61	14.38	13.02	15.51	.....	.....
1942—305	Rand. 5th	.....	15.64	13.41	15.50	.....	.....
1944—305	Rand. 6th	.....	.....	13.47	15.61	.....	.....
1946—312	Rand. 7th	.....	.....	.....	15.82	11.58	16.86
1938—302	Rand. 5th[1]	15.85	15.38	.....	15.98	.....	.....
1938—300	Sel. 4th	16.05	14.87	.....	15.38	.....	.....
(Second hybrid)							
1940—312	2nd	.....	.....	.....	.....	.....	14.53
1942—306	Sel. 3rd	.....	15.16	12.52	.....	11.84	15.91
1945—312	Sel. 4th	.....	.....	.....	.....	11.79	16.20
1945—315	Rand. 4th	.....	.....	.....	.....	11.72	16.14
1948—312	Sel. 5th[2]	.....	.....	.....	.....	.....	17.03
Local commercial check		16.95	15.18	13.26	17.12	11.92	18.62
U. S. No. 226		.....	.....	.....	16.83	.....	.....
Two times the standard error of a difference		0.57	0.76	0.78	0.74	0.80	0.60

[1] Random increase of selected 4th (1937-304)
[2] Selected for high sucrose with size of root given minor consideration.
Note: 1948 test at Ault, Colo., defoliated by hail July 30.

occur in which a difference between some two generations exceeds the difference required for significance in that particular trial, no one generation or line of selection is consistently high or low for any of these values throughout the series of trials.

The original selections of F_2 roots, from which the F_3 hybrid varieties were obtained, were on a rather broad base. In each case several hundred roots which were average or better in total gross sugar were grouped for the production of the F_3 variety. It seems possible that this selection eliminated most of the genes for very low sucrose content and retained a good share of the genes for higher sucrose content and large root size. Then, in advancing the generations by either method, segregations and new combinations of the factors determining sucrose content and root yield have maintained a general level of performance essentially like that of the original F_3.

In a single case the selection of roots for an F_5 (1948 seed No. 312) was for high sucrose percentage and a desired root shape, size of root being given little consideration. A single test of this F_5 indicated the possibility that quality of the variety had been improved at some sacrifice of root yield, with the yield of gross sugar remaining essentially the same as for the F_3 and the two F_4 generations of this variety.

In a single test (Ault, Colo., 1949) the F_2 of one of these hybrids was

Table 3.—Gross pounds sugar per acre of sugar beet x red, globe garden beet hybrid varieties and commercial sugar beet check variety. Data given as 6-plot averages.

Seed No.	Generation	Fort Collins, Colo., tests				Ault, Colo., tests	
		1939	1943	1945	1949	1948	1949
(First hybrid)							
1935—520	Sel. 3rd	4,614	4,786	3,951	7,073	3,126	8,290
1937—304	Sel. 4th	4,792	4,531	3,802	6,625	.....	.....
1939—303	Sel. 5th	.....	4,663	4,230	6,954	.....	.....
1939—300	Sel. 5th	.....	4,904	.....	6,705	.....	.....
1942—309	Sel. 6th	.....	4,908	4,244	7,017	.....	.....
1944—306	Sel. 7th	.....	.....	3,924	6,961	3,166	8,371
1946—311	Sel. 8th	.....	.....	.....	7,140	.....	8,822
1938—301	Rand. 4th	3,960	4,557	3,925	7,038	.....	.....
1942—305	Rand. 5th	.....	5,155	3,685	6,910	.....	.....
1944—305	Rand. 6th	.....	.....	3,644	7,006	.....	.....
1946—312	Rand 7th	.....	.....	.....	6,601	3,045	7,911
1938—302	Rand. 5th[1]	4,308	4,698	.....	6,488	.....	.....
1938—300	Sel. 4th	4,490	4,785	.....	6,720	.....	.....
(Second hybrid)							
1940—312	2nd	.....	.....	.....	.....	.....	7,492
1942—306	Sel. 3rd	.....	5,713	4,054	.....	3,484	8,502
1945—312	Sel. 4th	.....	.....	.....	.....	3,420	8,434
1945—315	Rand. 4th	.....	.....	.....	.....	3,646	8,200
1948—312	Sel. 5th[2]	.....	.....	.....	.....	.....	8,230
Local commercial check		4,663	4,628	3,748	7,116	2,987	8,270
U. S. No. 226		.....	.....	.....	6,587	.....	.....
Two times the standard error of a difference		693	530	378	704	297	645

[1] Random increase of selected 4th (1937-304)
[2] Selected for high sucrose with size of root given minor consideration.
Note: 1948 test at Ault, Colo., defoliated by hail July 30.

included. The yield of roots of this F_2 was not significantly different from the yields of the selected F_3 and the two F_4 generations. However, the percentage sucrose of the F_2 was significantly lower than that of the later generations. Apparently selection did eliminate factors for low sucrose.

Data from six of the more comprehensive tests of these hybrids and their advanced generations are summarized in Tables 1, 2 and 3.

Conclusions

1. These two selected F_3 sugar x garden beet hybrid varieties have produced high yields of roots with slightly lower sucrose percentages than the comparable commercial sugar beet variety.

2. Advancement of the generations of these hybrid varieties with continuous selection or at random has not materially changed the performance of the variety.

3. These trials indicate that a selected F_3 hybrid beet variety could be increased for commercial use, with or without further selection, without materially changing the character of the variety. If this conclusion is true the production of hybrid beet varieties for commercial use from even wide crosses becomes practical since the task of selecting and testing a large number of F_2 roots for the F_3 hybrid variety would not have to be repeated in the later generations while the seed stock was being increased to commercial quantities.

Performance of Three Male-Sterile Sugar Beet Hybrids

ALBERT M. MURPHY, G. K. RYSER, C. H. SMITH, AND F. V. OWEN[1]

The good performance with respect to yield and other qualities as obtained with the first male-sterile hybrid sugar beet variety, in which the inbred CT9 was the pollen parent, was reported in the 1946 Proceedings of this Society[2]. Three years' results with additional hybrids involving the same highly self-fertile inbred are shown here in Table 1 and in descriptions which follow.

Although the first hybrid appeared very promising, it was believed advisable to emphasize sucrose percentage in later work. This was accomplished by a series of hybridizations of inbred CT9 with varieties of the sugar type. The hybrid S.L. 6105, shown in Table 1, was derived by utilizing male steriles from the high-sugar, curly-top-resistant variety U.S. 35 as the female parent. The hybrid S.L. 6106 was derived by utilizing male steriles from U.S. 41 (U.S. 35 x U.S. 22/3) as the female parent. The hybrid S.L. 7101 was a reverse combination and was designed to incorporate maximum disease resistance. It was produced by utilizing CT9 MS (a third backcross generation stemming from CT9) as the female and S.L. 72 (second curly top resistant selection of U.S. 22/3) as the pollen parent. The curly top resistance of S.L. 6105 and S.L. 6106 was good and roughly comparable with that of U.S. 22/3. The curly top resistance of S.L. 7101 was remarkably high. This is explained by the high disease resistance derived from both parents combined with the vigorous growth of the F_1 hybrid beets.

In Table 1 the average over-all gain in sugar per acre shown in the Utah and Idaho tests for S.L. 6105 amounts to about 15 percent as compared with the variety U.S. 22/3, while S. L. 6106 shows a gain of about 18 percent. In every case these hybrids exceeded U.S. 22/3 in tonnage and also in sugar percentage. S.L. 6105 was somewhat superior to S.L. 6106 in sucrose percentage. S. L. 6105 exceeded the yield-type variety, U.S. 22/3, in tonnage and was nearly comparable to the sugar-type variety, U. S. 35, in sugar percentage.

The hybrid S.L. 7101 was also superior to U.S. 22/3 in the agronomic tests with results shown in Table 1 but was inferior to S.L. 6105 and S.L. 6106. In additional tests at Jerome, Idaho, where the curly top disease was more severe, S.L. 7101 excelled all other varieties tested. Since the extreme disease resistance of S.L. 7101 is not needed in most areas, hybrids resembling S.L. 6105 and S.L. 6106 would be more generally preferred.

Advantages and Disadvantages

The CT9 hybrids have other favorable characters in addition to increased yield and curly top disease resistance. Like the inbred parent the

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[2] Owen, F. V. Inbred lines from curly-top-resistant varieties of sugar beets. 1946 Proceedings American Society of Sugar Beet Technologists, pp. 246-252.

hybrid beets have shown an especially smooth clean root with low dirt tare as it is pulled from the soil. In the Utah tests the CT9 inbred and its hybrids have shown resistance to a petiole and crown rot which often takes a toll of two or three percent or more of beets in the variety U.S. 22. These good characters probably can be improved upon because there are now many different sub-lines from CT9 in the sixth generation of inbreeding. Tests in California, conducted by Charles Price and J. S. McFarlane, have shown that CT9 and its hybrids are extremely susceptible to the downy-mildew disease. Likewise, tests by Dewey Stewart at Beltsville have indicated a high degree of susceptibility to *Cercospora* leaf spot for the CT9 inbred. There may be other difficulties as more experience is gained. At Toppenish, Washington, the CT9 hybrids, in tests conducted by the Utah-Idaho Sugar company, gave good yield increases in 1947 and 1949, but in 1948 the yield was no better than that for U.S. 22/3. Much injury by lygus bugs occurred in 1948, and it is possible that the CT9 hybrids were relatively more susceptible to this injury than other varieties.

Table 1.—Gross sugar per acre of three male-sterile hybrids compared with U.S. 22/3.

Location	Year	U.S. 22		Male-sterile hybrids[1]		
				S.L.6105	S.L.6106	S.L.7101
		Lbs.	Percent	Percent	Percent	Percent
Twin Falls, Idaho	1947	5,457	100	106	109	
	1948	7,403	100		116	110
	1949	9,158	100	116	120	109
Granger, Utah	1948	6,994	100		122	111
	1949	7,240	100	123	122	110

[1]Description of hybrids:
S.L.6105 = U.S. 35 MS x CT9
S.L.6106 = U.S. 41 MS x CT9
S.L.7101 = CT9 MS x S.L. 72, a curly-top-resistant selection of U.S. 22/3—has been designated as S.L. 72.

Future Possibilities

The male-sterile hybrids derived from the CT9 inbred are not immediately available for commercial use. However, they are regarded as illustrative of the possibilities in this line of work. The male-sterile equivalent of an inbred, produced by successive backcrosses, has many advantages for hybridization work as compared with the use of the inbred as a pollinator. However, the obtaining of complete male sterility in the backcross populations from CT9 has involved some difficulty. The fourth backcross generation utilized in 1949 showed approximately three percent pollen producers which necessitated careful roguing of the seed field at the bud stage prior to the opening of the flowers. Necessity for this roguing work may be avoided by careful progeny tests. Some selections from CT9 have already produced lines which in hybrid combinations appear to give 100 percent complete male sterility. New sub-lines from CT9 have also been obtained which in their respective phases appear to be much better as either pollen or seed producers. Many other new curly-top-resistant inbreds which carry the proper Mendelian characters are also being produced and compared.

The production of desirable inbreds and their utilization in hybridizations offer a great challenge to the sugar beet breeder. The cytoplasmically-inherited male-sterility factor affords an efficient method for utilization of inbreds. Male sterile equivalents as obtained by backcrossing should greatly facilitate exchange of materials between sugar beet breeders. Such cooperation should serve to bring all efforts in this direction together for maximum benefit to the entire sugar beet industry.

Summary

Results obtained with three male-sterile hybrids, S.L. 6105, S.L. 6106, and S.L. 7101, are summarized. The new hybrids were significantly better in yield of sugar per acre than the commercial variety U.S. 22/3. The cytoplasmic male-sterility factor offers excellent possibilities for utilization of inbreds in the breeding program.

Methods of Utilizing the Male Sterile Factor in Sugar Beet Seed Production

SAM C. CAMPBELL[1]

The information contained herein reports the experiences of West Coast Beet Seed Company in the production of seed from plantings of alternate strips of male sterile material and pollinator. Only a very small amount of the acreage of our company has been devoted to plantings in which this "strip planting" arrangement has been used. The plantings have been confined almost entirely to the production of stock seed. There are indications, however, that in the near future sizable quantities of commercial seed will be produced by this method.

In 1948 and 1949 rather large amounts of commercial seed were produced from stock seed comprised of a mixture of male sterile material and pollinator. Production by this method of planting presents no particular problem as the fields are planted and harvested in the usual manner. Proper fertilization of the male sterile seed should occur due to the frequency of pollinating plants in the row.

The production of seed in fields where the "strip planting" method is used presents a number of problems. At planting time precautions must be taken to insure that seed of each of the two strains will not become mixed in any way. The seed of each strain is planted separately in alternate strips through the field. Each planted strip is set aside from the other by an unplanted area of several feet to insure that branches of the two strains will not become entwined and cause mixing of the seed at harvest time.

In planting, we have found it advantageous to use two drills, each containing seed of the two strains to be planted. If only one drill is used, it is necessary to clean it thoroughly following the planting of each strip. The use of two drills eliminates the cleaning up process and saves a great deal of time.

Care of the seed crop during the growing season requires no different cultural practices than usual, other than keeping the unplanted areas between the strains clean cultivated.

In the Pacific Northwest, where the overhead type of irrigation is used, the strip planting arrangement offers some advantage in the irrigation of the crop. The movement of lateral sprinkler pipe across a field at a time when the seed stalks are 6 to 7 feet high, and heavily entwined, has long been one of the most difficult jobs in growing seed. These lateral lines usually are placed at 60-ft. intervals. With growers, whose irrigation systems are such that the lateral lines run with the beet row, it has been possible for us to arrange the spacing of the planted strips so that an unplanted area will occur where the sprinkler line is to be placed. The open space afforded by the unplanted area will greatly facilitate the movement and coupling of the sprinkler line.

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In harvesting the crop, the windrowing of all strips of one of the strains is completed before starting on the other. A self-propelled windrower, which cuts and windrows the seed directly over the same rows cut, keeps the windrows separated by the unplanted area. The threshing of the strips is performed in the same manner as the windrowing in that all strips of one strain are threshed before starting on the other. The seed is usually delivered to the warehouse about as fast as it is threshed so that there is very little chance that the bags will become mixed in the field. The two strains are given different lot numbers and all bags are tagged as they are threshed. Close supervision, however, is required in the harvest and delivery of seed from these fields.

Figure 1. View of field in which seed of the male-sterile variety and of the pollinator were planted at a ratio of rows, 6 : 1. Salem, Oreg., Mar. 24, 1949.

Probably the most important factor to be considered in the production of seed by the strip planting method is the maximum utilization of the ground area of a given field in the planting of the male sterile strain, yet have sufficient pollinator for proper crossing. The seed produced from the pollinator may or may not have much commercial value. If the pollinator is eliminated, following the flowering period, the ground area represented by it, plus the unplanted areas, amounts to a considerable portion of the field from which there is no seed production. In our agreements with growers who have produced seed by this method we have paid them for the non-producing areas of their fields on the basis of the amount of seed these areas would have produced had they been planted or harvested. This amount

is calculated by applying the average yield of seed from the area actually producing seed to the area which produced no seed. Under this method of settlement with growers, it can be seen readily that the cost of seed actually produced is increased significantly by applying to it costs incurred by the non-producing areas.

In all our field plantings to date, we have arranged the spacing so as to include a pollinator strip on the side borders of the field. We have no particular reason for doing this other than that it would appear that if the male sterile material were almost surrounded by pollinator, the chances are better for proper fertilization. The planting of both side borders, however, increases the percentage of land area in pollinator and unplanted strips with a corresponding reduction in the percentage of the land area in male sterile.

In two fields harvested in 1948 and 1949 there was a rather wide variation in the ratio of rows of pollinator to rows of male sterile. In one field of 17 acres, the planting consisted of 12-row pollinator strips and 48-row male sterile strips or a ratio of 1 : 4, not including one border. In the other field of 5 acres, 4-row pollinator strips were planted to 48-row male sterile strips indicating a ratio of 1 : 12, not including one border. The unplanted strips in both fields were 10 feet in width or the equivalent of 4 rows. In two fractional acre plots, the ratio of pollinator to male sterile was 1 : 5 in one case and 1 : 10 in the other. The separating strips in both cases were 1 row. The effect of the different ratios on the percentage of land area utilized for each of the components and the results of production are shown in Table 1.

It will be noted that the yield of male sterile seed from both the larger field plantings and the fractional acre plots is exceptionally good. The germination of the seed was higher in all instances, except one, than the over-all average germination for the year in which this seed was produced.

An item of interest which the table reveals is that where the row to row ratio is the same, as in the fields for 1950 production, the percentage of land area in male sterile increases as the size of the field increases. Likewise, the percentage of land area in pollinator increases as the size of the field decreases.

The 48-row male sterile strip has been considered by some breeders to be too wide for proper crossing. The thought in this connection is that with male sterile lines which are not completely male sterile, selfing will occur to a greater extent where the source of pollen is too far removed. The only means we have of checking this is to take samples from different locations in a male sterile strip to see whether any significant differences in germination will occur. In the field shown in Figure 1 samples were taken from windrows on each side of a male sterile strip and also from a windrow in the center of the strip. Germination of the sample from the center windrow, which was approximately 55 feet from the nearest source of pollen, was 94.75%. Germination of the samples from the windrows on each side of the male sterile strip, or approximately 12 feet from the nearest source of pollen, were, respectively, 95.25% and 93.50%. The results of this test are encouraging but probably do not prove that the germination of the seed from the center strip was not the result of selfing.

All male sterile strips in fields for 1950 production have been reduced to 24 rows. Four-row pollinating strips have been used entirely, and the separating area has been reduced to 6 feet or the equivalent of 2 rows. Under field conditions the number of pollinating rows in a strip should probably be no less than four. The tendency toward lodging and breaking off of seed stalks appears to be greater when fewer rows are planted. Although

Table 1.—Rate of seed production from male-sterile plants of a number of fields in which the rows of male-steriles were planted in alternation and at various ratios to the rows of the pollinator variety. Oregon 1949, 1950.

Field	Acres	Rows Per Strip			Approximate Percentage of field			M. S. Yield	Germ.
		Pollinator	Blank	Male-Sterile	Pollinator	Blank	Male-Sterile		
					Percent	Percent	Percent	Pounds	
A	17.0	12	4	48	22.2	10.6	68.2	3223	95.50
B	5.0	4	4	48	9.8	12.8	77.4	3770	87.00
C	0.1	1	1	5	12.5	25.0	62.5	4560	91.00
D	0.6	1	1	10	9.4	15.1	75.5	2338	83.00
For 1950 Production:									
E	12.0	4	2	24	13.8	12.3	73.9	.....	.....
F	8.0	4	2	24	14.7	12.2	73.1	.....	.....
G	1.5	4	2	24	18.2	15.2	66.6	.....	.....

we have not harvested any fields where the planted strips are separated by a 6-foot area, we believe this is the minimum distance which should be used. Even at this distance some of the seed stalks will fall against each other across the unplanted area and it will be necessary to set them up in place by hand prior to the harvesting of the crop.

As far as production in the Northwest is concerned, we believe the 4-row pollinating strip and the 6-foot separating strip will become more or less fixed, but the proper width of the male sterile strips has yet to be determined for the best practical results.

Summary

The utilization of the male sterile factor in sugar beet seed production is relatively new. Methods of production include both the planting of a mixture of male sterile strain and pollinator, and the planting of alternate strips of male sterile strain and pollinator.

The alternate strip planting arrangement involves a number of factors which are not common to the method of planting the mixture. Precautions must be taken to insure that the planting stock of the two strains, and the resulting production, will not become mixed in any way. This is accomplished by planting the two strains separately, leaving an unplanted area between each strain. At harvest time the two strains are harvested separately.

The most important factor in the production of seed by the strip planting method is the maximum utilization of a given ground area in the production of the male sterile strain, yet have sufficient pollinator for proper fertilization. The percentage of pollinator used in fields has varied from about 9.4% to 22.2% while the percentage of male sterile has varied from about 68.2% to 77.4%. Under all distribution methods used, yields of male sterile seed seemed to be normal and the germination was average or above.

Further trials and studies will be required before the optimum ratio of the amount of pollinator to the amount of male sterile can be determined.

The Sugar Beet Breeder's Problem of Establishing Male-Sterile Populations for Hybridization Purposes

F. V. OWEN[1]

Cytoplasmically inherited male sterility in sugar beets offers many advantages to the sugar-beet breeder provided the desired male-sterile populations can be made readily available to him. Genes which interfere with, or which are complementary to, the cytoplasmic inheritance deserve special consideration. Evidence indicates the operation of at least two such genes, one of which may be considered to have a major influence and the other a minor influence. Certain hermaphrodite beets, designated type O (3)[2], when used as pollen parents in crosses to male steriles, produce offspring all of which are completely male sterile.

Genetic Interpretations

With information available the inheritance of this type of male sterility in beets may be considered to be approximately as follows:

N = normal cytoplasm
S = male-sterile cytoplasm
X = major gene
Z = minor gene

All genotypes carrying N cytoplasm are normal pollen producers regardless of the *X* and *Z* genic constitution. Type O hermaphrodites may be considered to be N*xxzz*. Completely male-sterile beets are assumed to be S*xxzz*. These S*xxzz* females crossed with N*xxzz* hermaphrodites produce the desired S*xxzz* populations. The presence of *X* or *Z* with S cytoplasm presents a complicated situation with many intermediate semi-male-sterile types, some of which may be more or less normal pollen producers.

Indexing Hermaphrodite Stocks

Indexing of beets to determine the "type O" or N*xxzz* hermaphrodites requires some method of preserving the genotypes until their hybrids to male steriles can be forced to flower so they may be classified properly for male sterility. Both vegetative clones and self-fertile lines are especially useful for this purpose. In preliminary indexing work on a large scale, it is difficult to avoid errors, but any procedure which increases the proportion of N*xxzz* genotypes in a population may be helpful. In self-sterile populations known to possess a high proportion of N*xxzz* individuals the beets may be crossed in pairs with an index made from each member of the pair. Methods of obtaining selfed seed from partially self-fertile beets should have good possibilities in connection with this indexing work.

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[2] Numbers in parentheses refer to literature cited.

Frequency of Nxxzz Hermaphrodites

Fortunately, the much desired *Nxxzz* hermaphrodites appear to be rather common in commercial varieties of sugar beets, at least in the curly-top-resistant varieties investigated by the writer. In a previous publication (2), reference is made to progeny tests with 91 beets taken at random from these varieties. The progeny tests indicated that 27 of the 91 beets were of constitution *Nxxzz*. Later work has shown that preliminary tests do not always differentiate between *Nxxzz* and *NxxZz* hermaphrodites because of the small effect of the minor *Z* factor which can not be detected readily. Theoretically, one might assume that *NXXZZ* and *Nxxzz* hermaphrodites would appear with equal frequency, but experience has indicated that this is not the case. For unknown reasons the *NXXZZ* types have rarely if ever occurred while *Nxxzz* hermaphrodites have been detected frequently. Genotypes of possible constitution *NxxZz* were predominant in one year's progeny tests from beets of variety US 35/2.

Homogenic Male-Sterile Populations

Building up reliable homogenic male-sterile populations is an important procedure in connection with the indexing work. Data presented in Table 1 illustrate the danger in assuming that all male-sterile beets have the same *Sxxzz* constitution. Some beets which may be considered *SxxZz* in constitution may appear completely male sterile and slight environmental variations may make a considerable difference. Furthermore, some results indicate that certain complementary genes possess a dominant rather than a recessive influence. Individuals taken from populations, all individuals of which are completely male sterile, have a greater chance of being homogenic than if they are taken from a segregating population. It appears safer to work with old reliable male-sterile populations rather than to take too many chances with new untested populations.

Table 1.—Effect of different male steriles crossed with the same pollen parent.

Male-sterile female	Pollen parent	Male sterile	Classification of progeny		
			Semi-male sterile		Normal pollen producers
			No. 2	No. 3	
		Number	Number	Number	Number
03 MS[1]-1	CT9-61	31	15	4	0
03 MS-2	do.	24	0	0	0

[1]03MS represents the F_1b_1 or first backcross generation to the annual inbred 03.

Use of Annual Growth Habit

At Salt Lake City a self-fertile annual inbred has been developed of possible constitution *Nxxzz*. This inbred, designated "03" is recessive (*rr*) for hypocotyl and crown bud color which is an added convenience. Male-sterile F_1 hybrids with 03 were used for indexing work in 1948. The first male-sterile backcross population was used in 1949 and the second male-sterile backcross is being grown for use in 1950. These annual male-sterile *rr* beets have decided advantages for indexing work with the facilities available at Salt Lake City. A large number of plants is held vegetative under short winter days in the greenhouse and groups of the plants are brought

into flower under long photoperiods at regular intervals to correspond with the development of the hermaphrodite breeding stocks to be tested. With facilities available at Salt Lake City it is impossible to control the flowering of biennial beets as easily as that of the annuals.

After a series of hybrids to unknown hermaphrodites is completed, the breeder is eager to force the new progeny to the flowering stage as rapidly as possible. The dominant annual or *B* factor (1) is helpful in this respect. The better the facilities for long photoperiods with good light quality and intensity, the more rapid the flowering for the F_1 annual beets. At Salt Lake City this indexing work was completed with these annual beets in February and March, but some preliminary trials with artificial light during the summer indicate that the same information might be made available the previous September.

Effects of Contamination

It is difficult to avoid all sources of contamination in connection with extensive indexing work. In making the test crosses to male steriles by means of paper bags, there are advantages in the greenhouse cultures to avoid insect troubles and weather hazards. It is advisable to hold open pollen-producing inflorescenses to a minimum. Some measure can be made of the amount of contamination by using *rr* MS females. In *rr* ♀ x *rr* ♂ combinations in the presence of possible contaminating R pollen, the appearance of R seedlings in the offspring gives an estimate of the amount of contamination. Likewise in *rr* ♀ x *RR* ♂ combinations the appearance of *rr* seedlings gives an equally valid estimate of contamination. At Salt Lake City in 1949 there were 95 such progenies and the average contamination was estimated to be 0.3 percent. As long as there is a source of contamination, occasional unconformity to expected results must be expected and allowed for.

Need for More Information

There is need for more information regarding the cytoplasmically-inherited male-sterility in beets, both with regard to the constitution of the cytoplasm and the genic constitution which may modify the cytoplasmic influence. There is no absolute assurance that all sources of the male-sterile beet carry the same cytoplasm, and evidence indicates quite definitely that the influence of more than two genes may be encountered with variable types of influence. It is important that different sources of male-sterile beets be studied carefully to determine what differences may exist. There is even a possibility that the whole theory may need revision when more information is obtained.

Summary

Male sterility offers great opportunities to the sugar beet breeder; it also offers many challenges. A technical, but nevertheless important consideration, is the breeder's ability to produce pure homogeneous male-sterile populations. As little as one percent of pollen producers in male-sterile populations is not considered satisfactory for certain types of hybridization work. The presence of pollen producers necessitates careful roguing before flowers open to assure complete hybridization.

Indications are that pure male-sterile populations may be obtained by careful attention to pedigree records. Certain hermaphrodite beets, designated type O, when used as pollen parents in crosses to male steriles, produce offspring all of which are completely male sterile. Such hermaphrodites may represent the double homozygous recessive for two or more genes whose effect is complementary to that of the cytoplasmic influence.

The breeder's task is to index adequately his hermaphrodite populations in order to recognize the desired type O beets. Several problems of technique are involved in this process and some difficulties have been encountered. More trouble seems to be caused by the gene, or genes, with the minor influence because it is more difficult to detect. One useful procedure has been the incorporation of male sterility into an annual beet whose flowering can be induced without the use of low-temperature treatments.

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A Method of Selection for Earliness of Root Development in Sugar Beets

V. F. SAVITSKY[1]

Sugar beet varieties distinguished by earliness of root development are valuable for different areas, different latitudes, different elevations, different humidity conditions, etc. Varieties showing large differences in sugar percentage differ also in earliness of root development. Selection conducted in different climates has produced varieties with different degrees of earliness in root development. This process can be accelerated by direct selection on rate of root growth. Such selection has led also to good results in connection with increased yield. Success of selection for rate of root development is facilitated by selection during the vegetative period when differences in this character are clearer. The largest variability in root weight in sugar-beet populations was observed during the early period of growth. The variability of root weight diminished during development, and, as an average of 5 years' results, showed coefficients of variation of root weight for the 6 months May through October of 79, 56, 55, 45, 42 and 44, respectively.

The difference in yields between different varieties decreases also toward the end of the vegetative period (Table 1).

Table 1.—Average weight of root expressed as percentage of that in U.S. 22/2, Salt Lake City, 1948.

	June 9	July 23	August	September	October
	Percent	Percent	Percent	Percent	Percent
Barres	223	228	224	220	179
E-type, U.S. 22/2	100	100	100	100	100
Z-type, U.S. 35	97	87	92	98	97

Selection work for increased root weight showed that the percentage of correctly selected roots is higher in the middle of the summer than in the fall (Table 2).

Selection was made in E-type and Z-type varieties (Table 2). Both of these varieties were planted at the same time in alternate plots each containing 120 plants. Five repetitions of this experiment were harvested in late July and on October 10. In both harvest dates all harvested roots were weighed individually, thus the effect of selection in the summer and in the fall could be compared. Twenty percent of the largest roots were selected in the E-type variety in the summer and in the fall. Selection of the same root-weight classes at both dates (Table 2) was also made in the Z-type variety. The percentage of selected roots in the Z-type variety appeared much higher in the fall than in the summer. In the fall the percentage of the large roots proved almost the same in the E-type and Z-type varieties. Therefore, selection in the fall was less efficient than selection in the summer. The progeny of the groups selected in the fall usually showed the same properties as the variety from which it originated.

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Table 2.—Root weight in E-type and Z-type varieties.

Variety	Root weight in grams										
	10	20	30	40	50	60	70	80	90	Over 100	Total three heaviest groups
	%	%	%	%	%	%	%	%	%	%	%
					July						
E-type	3	5	7	8	11	25	17	6	8	10	24
Z-type	9	15	17	25	16	10	4	2	2	—	4
	Root weight in grams										
	100	200	300	400	500	600	700	800	900	Over 1000	
					October						
E-type	4	8	13	13	15	13	12	9	5	8	22
Z-type	6	9	16	17	15	12	9	8	3	5	16

A study of ontogenetic development in beets suggests a new method of selection for earliness of root development:

1. The first stages of ontogenetic development are characterized by a rapid rate of growth of leaves in all races and varieties of beets, sugar beets, mangels, red garden beets, etc. The growth rate of roots increases later.

2. The enlargement of tap-roots is a secondary process and it does not represent a fixed character for all races of *Beta vulgaris*. The critical time of development, when the weight of the root exceeds the weight of the leaves, does not occur simultaneously in different varieties (even in sugar beets) and does not depend upon the weight of the seedlings or upon the final yield of the roots in the fall.

3. The period or phase in the ontogenetic development when the roots begin to grow faster than the leaves is governed by heritable characters. This change in development occurs 10 to 40 days earlier in the E-type variety US 22/2 than in the Z-type US 35 (Table 3).

4. The time at which the change in rate of growth of leaves and roots occurs clearly classified the varieties according to their agricultural earliness. Varieties in which the change occurs early are early maturing and their comparative yields in relation to the sugar beet are higher at mid-season than at the end. The late-maturing varieties have a higher increment of root growth at the end of the vegetative period than at mid-season.

Table 3.—Yield of different varieties shown in percentage from that of U.S. 22/2 in August and November, Salt Lake City, 1948.

Variety	Yield of roots	
	August 9	November 3
	Percent	Percent
Swiss chard (very late root development)	45	48
Z-type sugar beet, U.S. 35	92	97
E-type sugar beet, U.S. 22/2	100	100
Mangel (early root development)	224	177
Red garden beet (early root development)	119	58

Selection for Rate of Root Development

Each population of beets contains races with early and late root development but either can show high or low productivity. Therefore, when high-yielding varieties with early root development are selected, the degree of earliness and the level of productivity must be taken into consideration. Experimental trials are helpful in showing the best way to select plants which possess a high rate of leaf growth in July and August together with early root development (Table 4).

Table 4.—Average weight per root in mid-season of progenies selected from E-type and Z-type varieties, and of hybrids between the two selected groups.

	From parental varieties		From the hybrid
	E-type	Z-type	
	Grams	Grams	Grams
Group with early root development	351	342	365
Group with late root development	301	277	272

The progenies obtained from the group of plants twice selected in the summer for early root development were also higher yielding when tested during the harvest in October. Selection in the hybrid population for two generations was more effective than selection in either of the parental varieties.

It is best to select for earliness of root development in commercial beet plantings. The quantity of selected plants does not exceed one percent and does not damage the planting. Selections should be made at the time the differences in the weight of the root between varieties appear clear, which is usually in July or August. Beets with good tops are chosen first. Then the foliage and the root from each selected plant should be weighed separately. Beets with a root weight exceeding the top weight form a group of "early maturing plants." The selected plants should then be transplanted. The rate of root development can be checked again during harvest in the fall.

Summary

Largest variability in root weight in sugar beets occurred in the early period of growth, differences between varieties decreasing toward the end of the vegetative period. When comparisons were made involving both sucrose and yield types of sugar beet, it was found that selections for root weight were less efficient when done in the fall than when they were made in summer. The time at which the ratio of root weight to leaf weight decreases is governed by heritable characteristics and the decrease occurs early in early-maturing varieties. Experimental trials indicate that the best way to select sugar beet plants is to choose those possessing a high rate of leaf growth in July and August, together with early root development.

A Method of Determining Self-Fertility and Self-Sterility in Sugar Beets, Based Upon the Stage of Ovule Development Shortly After Flowering

HELEN SAVITSKY[1]

Sugar-beet-pollen grains germinate after selfing on the surface of the stigma, but in the tissues of the pistil the growth of the pollen tubes becomes slower or stops completely. For eight or nine days after selfing the pollen tubes are unable to reach the embryo sacs and for the most part the ovules remain non-fertilized. In three or four days after selfing, the synergids are not broken through, but their outlines become wavy and their shape irregular. In seven or eight days the protoplasm in non-fertilized embryo sacs, in synergids and egg-cells, is constructed into dark stained threads (Figure 1a). The central nucleus is covered with chromatin threads which protrude through the membrane. In 10 or 12 days only a dark clump remains from the egg-cell and synergids, the ovules become shrivelled and the embryo sac is tightened by the nucellus.

The slow growth of the pollen tubes and non-occurrence of self-fertilization is the most important cause of self-sterility. If the pollen tubes after selfing grow fast enough and if fertilization takes place, we see another factor which provokes self-sterility in beets. This factor is the destruction of the newly formed zygote. Sometimes the embryo sac degenerates before the embryo starts to develop. The central nucleus of the embryo sac divides and forms some nuclei of the endosperm, but the egg-cell begins to degenerate before dividing.

In the other cases the embryo starts to develop normally but at a certain stage the growth ceases and degeneration takes place. At the stage when the embryo is globe-shaped, the cells of the degenerating embryo differ from the normal embryo by their dark staining nuclei and by the disappearance of the nucleoli. The endosperm nuclei have an abnormal shape, they are shrivelled and covered by the chromatin threads. At the stage of the heart-shaped embryo the contents of the cells degenerate

Figure 1. (See page 199) Ovule development in self-sterile sugar beets as contrasted with normal development. (a, upper right) Degenerating non-fertilized embryo sac. X1000; (b, upper left) degenerating embryo and endosperm after selfing. X330; (c, lower left) normally-developing embryo and endosperm after crossing. X330; (d, middle right) dark lump remained from non-fertilized ovule in 12 days after selfing. X15; (e, lower right) degenerating shrivelled seed after self-fertilization. X15.

[1] Collaborator, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, in cooperation with the Curly Top Resistance Breeding committee.

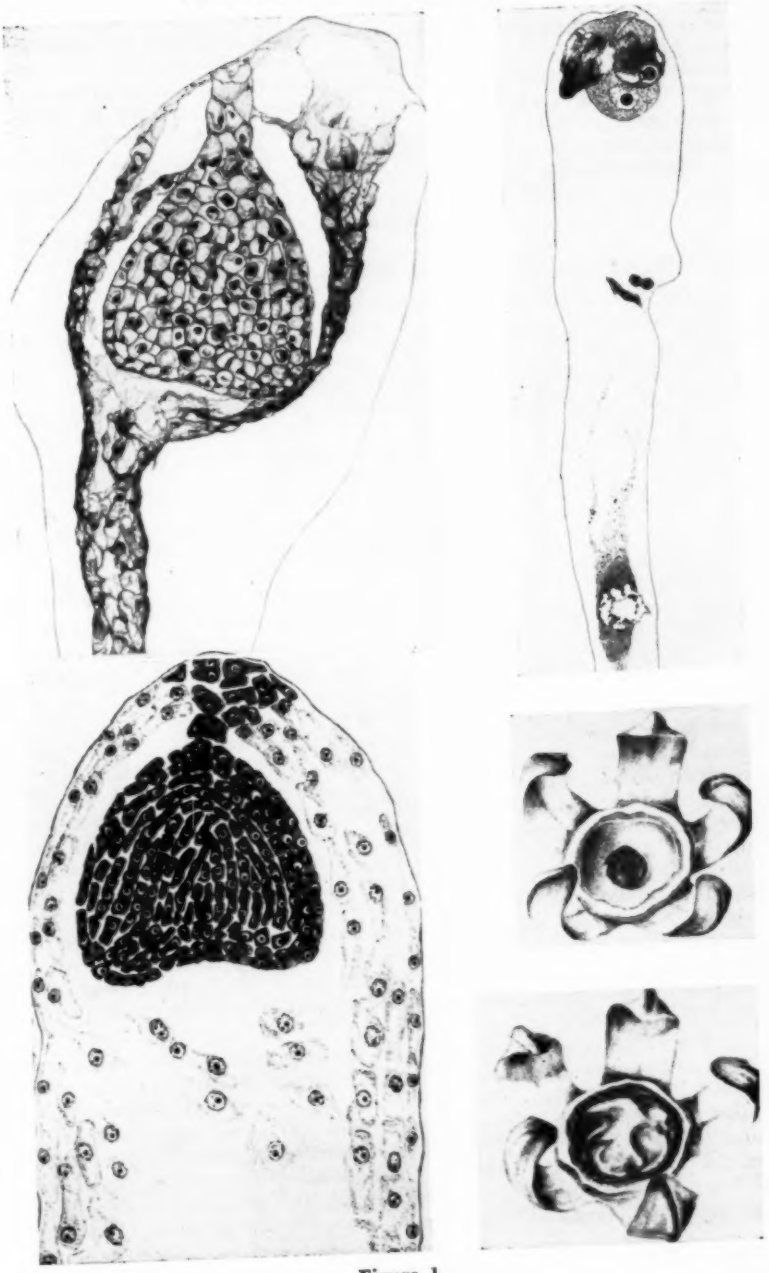

Figure 1.

(Figure 1b). The endosperm tissue is represented by a trace of demolished cells. In some ovules the embryo degenerates after having formed the seed-leaves. The seed leaves or cotyledons are curved and the root has a defective shape. The embryo cells are empty, in many places the cell membrane begins to degenerate. Simultaneously with the degeneration of the embryo sac, the ovule also degenerates. It becomes wrinkled and contracted and the seed coat is pressed in. The germination ability of selfed seeds is often very poor. This is caused by the death of the embryo and the absence of normal seeds in the developed seed-ball. Destruction of the embryo is the earliest manifestation of the degeneration process caused by genes which have a lethal action in the homozygote after selfing.

The rate of pollen-tube growth depends on the degree of self-fertility of the plant. The lower the percent of the fertilized ovules on the plant, the slower is the growth rate of pollen tubes, and the later the fertilization and the embryo development. We observed that in the highly self-fertile group nearly one-half of the plants (41.7%) were fertilized during the first day and one-half (50.1%) on the second day after selfing. Most of the partially self-fertile plants were fertilized on the second day after selfing (89.6%). In poorly self-fertile plants the growth of the pollen tubes is so slow that none of them were fertilized the first day and nearly half of the plants of this group (46.2%) were not fertilized for three days. Thus the rate of pollen-tube growth is associated with the degree of self-fertility. In some highly self-fertile plants the pollen tubes grow with the same rapidity by selfing as by crossing, but to produce a normal set of seeds the self-fertile plants must also possess the ability for normal development of the embryo (Figure 1c.)

Highly self-fertile plants may arise in populations as a consequence of mutation of a gene which provokes a high rate of pollen-tube growth after selfing and a combination of these genes with such genotypes as can undergo self-fertilization without degeneration of embryos. Partially self-fertile races may manifest different degrees of both of these processes. A poor degree of self-fertility could be caused either by the lack of self-fertilization or by the death of the embryos. When self-fertile races are involved in breeding processes, it may often be necessary to determine the degree of self-fertility of a plant during the time of its flowering. A simple method, based upon the stage of ovule development shortly after flowering, can be used to determine the degree of self-fertility. Non-fertilized ovules appear in 10-12 days after opening of the flower as small, dark lumps on the bottom of the expanded cavity of the ovary (Figure 1d). The ovules which have started to develop after selfing, but in which the embryos have degenerated, appear as large but shrivelled seeds within the cavity of the ovary (Figure 1e).

The branches of a plant intended for investigation must be bagged. The buds must be investigated in the summertime 10 to 12 days after they have finished flowering. The ovary must be opened and determinations made of percentage of (a) small dark ovules, (b) normal developing seeds and (c) shrivelled seeds. The percent of small dark ovules on the bottom of the ovary shows the percent of non-fertilized ovules and the percent of self-sterility of the race. In highly self-sterile plants almost all ovules appear as small dark lumps. The percent of normally developed seeds indicates

the degree of self-fertility of the plant. In highly self-fertile races almost all ovules are large, non-shrivelled and fill the cavity of the ovary. The amount of large but shrivelled seeds shows the amount of fertilized but dead ovules. They must be added to the amount of normally developed seeds to determine the degree of self-fertilization of the plant. At the same time percentage of shrivelled seeds indicates the amount of degenerating embryos and the influence of the second factor which provokes self-sterility. The degree of self-fertility or self-sterility of a plant can be established quickly and easily on the basis of this analysis. Then the plant investigated in this manner can be used for crossing or selfing.

Summary

Self-sterility in beets is caused by: absence of self-fertilization because of slow rate of pollen-tube growth, and degeneration of embryos after selfing. Non-fertilized ovules appear in 10-12 days after opening of flower as small dark lumps on the bottom of the expanded cavity of the ovary. Determination of the degree of self-sterility or self-fertility is based upon examination of ovules during the time of flowering of the plants.

A Quarter Century of Progress in Sugar Beet Improvement by the Great Western Sugar Company

H. E. BREWBAKER, H. L. BUSH AND R. R. WOOD[1]

Breeding work has been conducted by the Great Western Sugar Company since 1910. Previous reports have been made to this Society[2] of various phases of this work, and the general progress for the period 1922 to 1938 was evaluated in terms of breeding methods in the 1938 Proceedings pages 42-50.

Some very encouraging developments in new varieties which combine a high degree of resistance to leafspot *(Cercospora beticola)* with superior performance for both tonnage and sugar content seem to be of sufficient interest to justify a further report at this time.

In this connection, some attention will be focused on breeding methods. We do not intend to survey the method being used by various breeders except to observe that most of the commercial seed currently being used in this country is from varieties which have arisen either by mass selection or by some phase of progeny-test selection, in some cases with partial control of pollination by isolation methods. In our own work the progeny-test method has been used more or less consistently for most of the varieties of commercial value developed up to the present time. In recent years, however, several new unrelated sources of material have been introduced into the breeding program and it appears probable that some new genes for possibly both root production and sugar content have been acquired in this manner.

This report of progress will be confined to the improvement work conducted principally for the areas subject to attacks of the leafspot disease common in much of the area east of the Rocky Mountains.

Progress Since 1922

An attempt has been made to present graphically (Figure 1) the trend in "total sugar" content for the varieties of potential commercial value for the period 1922 to 1937 (each point on the curve for that period being a three-year mean) and the principal improvements in the form of commercial variety releases since that time. The curve for 1922-1937 was presented in 1938 and its significance discussed. The breeding program during that period resulted in a potentially new commercial variety each year, each such variety being tested against a standard to prove its comparative worth. The drop in total sugar indicated for the first two years after 1923 was considered to be the result of undue emphasis on sugar content. This being corrected in 1925, the curve showed a consistent rise for a few years, sloping off after 1930 or 1931 for no apparent gain for the next few years.

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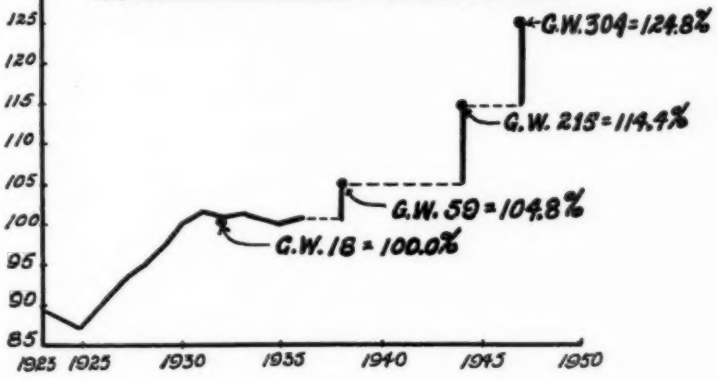
[2] Proc. Amer. Soc. Sug. Beet Tech., pp. 42-50, 76-9, 1938; 143-4, 147-8, 169-80, 1940; 322-5, 342-8, 1942; 259-262, 1946; 162-5, 175-8, 1948; 56-9, 1949 (Eastern Sec.).

In evaluating the results for these years it was pointed out that this pattern was similar to what corn breeders experienced in applying the ear-to-row method for adaptation of a corn variety to a new area. It was further concluded that except for possible improvements in yield through increased resistance to leafspot, there was not much to be hoped for by continuing the program without material change.

Fig. 1. Total Sugar in % of G.W. 18

-Quarter Century of Progress-



This conclusion, however, proved to be subject to the error of any long-time prediction, for in 1939 a variety which later became known as GW59 showed unusual promise in variety tests in which it was included for the first time. Curiously enough, a possible 25 to 50 percent of the inheritance of this variety traces back to one root, the remainder to a broad base of old family material. GW59 proved to be more tolerant to leafspot than the preceding commercial GW18, which character has no doubt had some influence in its performance record of 4.8 percent (see Figure 1) increase in total sugar over GW18 as an average of forty-two tests conducted over a period of 8 years.

Correlation Between Yield of Roots and Leafspot

In a study conducted in 1940, using a wide series of families planted with three replications at each of two locations, yield at Longmont, where leafspot did not develop, was correlated with leafspot estimates at Fort Morgan, where leafspot readings indicated a moderately severe epidemic. An r value of —.0516 was obtained, which was far from significant. From this it was concluded that a breeder could safely confine his efforts, so far as yield was concerned, to strictly LSR material. The direct effect of leafspot on yield and sugar content was well known. However, regression values for yield and percent sugar on leafspot, as determined from breeding

strain data, will serve to point up this relationship. These are given in percent of the standard variety (GW18) as follows:

Year	Location	Wt. of Roots	Percent Sugar	Total Sugar
1937	Longmont	3.62	0.80	Approx. 4.42
1938	Ft. Morgan	4.22	1.33	Approx. 5.55
1940	Ft. Morgan	1.72	0.39	Approx. 2.31

Leafspot developed later in 1940, hence its effect was less severe than in 1937 or 1938. The indicated loss in total sugar of from 2.31 percent to 5.55 percent for each unit of increase in leafspot estimate on the scale of 1 = none to 10 = complete necrosis shows how very important this disease can be as a limiting factor in production.

Recent Developments

Since the leafspot disease potentially is a limiting factor for much of the beet-growing area east of the Rockies, this character was sought for in most of the breeding strains studied. Breeding strain tests were conducted on an extensive scale. Major emphasis was placed on yield, sugar content, and leafspot resistance in the selection program. As many as 10,000 plots per year were necessary for a few years to carry all phases of the selection and testing program, not including seed production. Many new sources of potentially valuable material, among which were hybrids with *Beta maritima*, were included in the selection material. Many lots which possessed some resistance to leafspot along with some very undesirable qualities were taken through a careful screening plus a thorough polishing process. A synthesizing program followed, in which numerous possible combinations of strains from these various sources were brought back together, these re-combinations being then entered into variety tests at several locations in the four-state area served by this company.

Two of the more recent developments, GW215 and C304, have been quite thoroughly tested for three years in a total of twenty replicated variety tests, these results being shown in Figure 1 and summarized in Table 1.

Table 1.—Mean results 1947-9, twenty locations. (In percent of GW59).

Variety	Yield of Roots	Sugar Content	Total Sugar
GW59	100.0	100.0	100.0
GW215	102.5	106.8	109.6
C304	111.7	107.3	120.0
LSD 5% pt.	2.2	1.0	2.5

As will be obvious by comparison with GW59, the new varieties show improvement in both tonnage and sugar content, the increases for total sugar being tremendously significant in terms of the mean LSD values at the 5% point.

Variety 304 was tested (Table 1) in the "C" or "pedigreed" generation and reservations were withheld as to final estimates of its potential commercial value in due respect to a preceding study (1942 Proceedings, pp. 342-8, 1942) until a comparison with the commercial or "GW" generation became possible. This was accomplished using seed of GW304 harvested in Arizona in May, 1949, and planted in two locations in early June in comparison

with C304. The results presented in Table 2 represent a total of 16 replications for the two locations.

Table 2.—Late Planted Variety Test. (Mean two locations, 1949.)

Variety	Beets per Acre (tons)	Sugar (percent)	Sugar per Acre (pounds)
GW304	16.00	15.93	5,098
C304	15.91	15.87	5,050
LSD 5% pt.	.85	.42	333

From these data there appears to be no doubt of the equality of the two generations of variety 304.

Several other new varieties having arisen out of this broad program which offer much promise are shown in comparison with C304, three GW commercials and certain other varieties in Table 3, which summarizes results of tests at seven locations in 1949.

Table 3.—General Variety Test, 1949[a]. (Yield and sugar in percent of mean of all varieties.)

Variety	Yield[b] of Roots	Sugar[c] Content	Total Sugar	Leaf[d] Spot	Percent Bolters
B359	105.7	103.7	109.6	1.5	.07
C305	108.5	100.3	108.8	2.0	0
C304	104.7	103.0	107.9	2.4	.03
B389	101.4	104.0	105.6	1.6	0
GW258	103.0	101.0	103.9	2.8	.03
GW215	98.1	103.5	101.5	2.4	.04
C329	104.4	97.2	101.5	3.9	0
C455	105.2	96.2	101.2	1.4	.47
C381	92.8	106.2	98.6	1.8	0
H-125	98.9	98.9	97.8	3.0	0
R & G "N"	98.5	97.7	96.4	7.2	0
GW59	98.4	96.2	94.7	5.5	.03
GW85	92.7	100.0	92.7	4.3	.07
GW201	91.5	100.5	92.0	5.6	.01
US226	93.4	97.6	91.2	3.1	.17
LSD 5% pt.	3.1	1.5	3.5	----	----

[a] With two locations for leafspot and seven locations for all other characters. Six replicates per location.
[b] Mean yield all varieties in test = 22.98 tons.
[c] Mean sugar content all varieties in test = 15.84 percent.
[d] 0 = immune, 10 = complete necrosis.

Three new numbers (B359, C305 and B389) are statistically equal to C304 in total sugar production, this being true also in 1948 for B359 and B389 in a four-location test. Further tests will be necessary to determine the comparative value of these four varieties.

Particular attention might be called to certain of the lots in Table 3. GW258 resulted from a recombination of eleven short-rooted inbred lines. C329 is the only lot out of a wide series of crosses with European *Beta maritima* types which has survived the testing program to this time, and it needs some further improvement in resistance to leafspot. C455, resulting from a cross of *Beta maritima* from California with a GW LSR strain (see footnote 2, pp. 175-8, 1948), is a promising number, but it needs some im-

provement in sugar content and further reduction in the annualism or bolting tendency acquired from the *Beta maritima* parent. H-125 is a production by H. L. Kohls of Michigan Agricultural Experiment Station. The lot of R&G "N" used in this test was a 1948 European seed production, and while it proved to be much too susceptible to leafspot, it appeared at least equal to GW Commercial 59 in this series of tests.

One experimental-demonstrational type of test was conducted on a farm at McCook, Nebraska, where leafspot is generally severe. Plots were 8 rows x 1,294 feet, with three replications, all beets being weighed over the dump with samples taken for sugar. Results are summarized in percent of the GW commercial variety 59 in Table 4.

Table 4.—McCook Variety Strip Test, 1949. (Yield and sugar in percent of GW59.)

Variety	Yield[a] of Roots	Sugar[b] Content	Total Sugar	Leaf[c] Spot
GW59	100.0	100.0	100.0	6.7
GW215	114.7	110.3	126.5	2.0
C304	115.3	109.6	126.4	2.7
GW248	114.6	109.0	124.9	1.7
GW85	114.9	106.6	122.5	4.5
R & G "N"	102.0	98.6	100.5	8.5
LSD 5% pt.	12.0	4.3	13.5	—

[a] Mean yield all varieties = 17.12 tons.
[b] Mean sugar content all varieties = 15.38 percent.
[c] 0 = immune, 10 = complete necrosis.

The field was planted rather late in the spring and while leafspot was severe near harvest time, it did not have as much time to take its toll of injury as usual in this area. The superiority of the new LSR numbers over susceptible GW59 and a lot of R & G "N" acquired in 1939 is very striking. In this case, the moderately resistant GW85, which has been the commercial variety in this area in recent years, looked good in comparison with the more LSR numbers—a situation which probably would not hold in a year characterized by an earlier and heavier leafspot epidemic.

From the above results it appears that a new and considerably improved level of performance has been reached for both yield and sugar content in combination with a high degree of resistance to leafspot. At least four of these new numbers have been increased into commercial seed proportions to be in limited use by growers in 1950, and older numbers will be replaced as rapidly as adequate supplies of the new ones become available.

Other Desirable Characters

Using certain of the choice new LSR numbers, it is planned to improve by selection (either mass or mass plus one generation of selfing) or to introduce into the variety other characters which are known to be valuable but for which little effort has been expended in their behalf previously. These include:

a. Cold resistance[3]
b. Low respiratory activity[4]
c. Resistance to storage rots
d. Resistance to damping off, black root and mature root rots

[3] Reported in a separate paper in the 1950 Proceedings by the same writers.
[4] Reported in a separate paper in the 1950 Proceedings by R. T. Nelson and R. R. Wood.

e. Reduction in number of locules to mono- or bi-locular seed
f. Small and uniform crown

It is also planned to develop a cytoplasmic male-sterile equivalent of certain of the new varieties in order to facilitate crosses with other varieties, looking toward possible utilization of heterosis or hybrid vigor.

Selection in Self-fertilized Lines

The foregoing program anticipates a continuation of broad breeding methods closely associated with early possibilities for further improvement for particular characters.

The logical next step in our improvement program as it is planned involves an extensive application of the method of breeding so effectively used for corn; viz., that of selection in self-fertilized lines. Some investigations in this field have been conducted, both in Europe and in this country. The practical results to date from this method of breeding have been very limited, and not particularly exciting. We believe this to be due mainly to the fact that the work itself has been far too limited in extent, and that by expanding this work greatly it will be possible to make as great or even greater improvement than that represented by the new varieties reported in this paper as compared with previous commercial types.

There are admittedly certain problems such as partial to complete self-sterility in sugar beets; however, this may be partially overcome by doing the selfing under environmental conditions which are favorable to seed setting under bags or other isolators. This may be considered as a pseudo type of self-fertility. The self-fertility (S^f) gene may be employed to assure selfing in some lines.

The sugar beet breeder has one tool available in the form of cytoplasmic male sterility which is proving valuable in making crosses on a commercial scale, and which adds greatly to the assurance of success in an inbreeding and hybridizing program.

Summary

1. Evidence is presented to show a quarter century of improvement in yield and sugar production. In the early years the curve of improvement indicates genetic adaptation. Later improvements were considered to result from a broad search for new genetic sources, selection within these and recombination of the better strains.

2. Recent improvements appear by extensive test to produce as much as 25 percent more sugar per acre than GW18, which originated in 1932 and was the standard variety for much of the Great Western area for several years. These new varieties are very resistant to leafspot, and show improvement in both tonnage and sugar content over previous commercials. They will be in limited use by growers in 1950.

3. Plans for further improvement of these new varieties, as well as application of the method of breeding by selection in self-fertilized lines, are discussed.

The U.S. 15 Variety of Sugar Beet

G. H. COONS, DEWEY STEWART, CHARLES PRICE, AND HARRY A. ELCOCK[1]

Winter plantings of sugar beet in California have been made chiefly with one variety of sugar beet, U.S. 15. The non-bolting tendency of this variety, even if planted early in October in the Imperial valley or in November or December in the San Joaquin valley, or elsewhere in Southern California, made it the dominant choice for early seedings. More than any other variety, it is responsible for the development of sugar beet culture in the Imperial valley. The variety, in addition to its non-bolting character, has distinct advantage over other varieties because it has moderate resistance to curly top and relatively high resistance to downy mildew (*Peronospora schachtii Fckl.*) and rust (*Uromyces betae* (Pers.) Lev.). It is very susceptible to leaf spot (*Cercospora beticola* Sacc.) but this disease is never a factor in the Imperial valley and minor in other locations where U.S. 15 is grown. The higher curly top resistance of U.S. 56, also a non-bolting variety, has given it advantage over U.S. 15 in locations subject to curly top.

The U.S. 15 variety is a product of breeding research conducted at State College, New Mexico, in cooperation with the New Mexico Agricultural Experiment Station. Mass selection of highly resistant plants was made in 1927 in a field of R. & G. Pioneer sugar beets in which curly top had destroyed nearly all the plants. A second selection for curly top resistance was made from the progeny of the selected roots, high sucrose quality being also a factor in selection. Tests in California in 1932 and 1933 by C. A. Lavis and by F. G. Larmer in 1934 revealed the non-bolting character of the variety, as compared to that of European varieties or other curly top resistant strains. These findings, as well as the commercial possibilities of the variety, were confirmed by a large-scale test in 1935. The variety was made available to beet sugar companies through the Curly Top Resistance Breeding committee by direct increases, without selection, of the elite seed.

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[1] Principal Pathologist, Senior Agronomist, Agronomist and formerly Assistant Pathologist, respectively, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

Report on 1949 Tests of U.S. 216 x 225 and Other Varieties from Sugar Beet Leaf Spot Resistance Breeding Investigations of the U. S. Department of Agriculture

G. H. COONS, DEWEY STEWART, H. W. BOCKSTAHLER, G. W. DEMING, J. O. GASKILL, J. G. LILL, AND CHARLES L. SCHNEIDER[1]

Agronomic evaluation tests were conducted in 1949 with U. S. 216 x 225, U. S. 226 and with other U. S. varieties. Tests at a total of 16 locations were conducted by members of the staff of this Division in cooperation with State Agricultural Experiment Stations and by cooperators in the sugar beet industry. The cooperators in research organizations of the industry who contributed data are Perc A. Reeve and Grant Nichol, Farmers and Manufacturers Beet Sugar Association (tests at Saginaw and Sebewaing, Michigan, and Latty, Ohio); C. W. Doxtator, American Crystal Sugar Company (tests at Rocky Ford, Colo., and Mason City, Ia.); Kenneth Meyers, National Sugar Manufacturing Company (test at Sugar City, Colo.); C. E. Cormany and D. F. Peterson, Holly Sugar Corporation (tests at Torrington, Wyo.); H. E. Brewbaker and H. L. Bush, Great Western Sugar Company (tests at Longmont and Fort Morgan, Colo.); and Canada and Dominion Sugar Company (tests at Chatham and Wallaceburg, Ont.).

The varieties included in the agronomic evaluation tests were as follows:

S.P. 471802-00	Synthetic variety (6 unrelated lines)
S.P. 471803-00	Synthetic variety (US216MS and inbred lines "A" and "U")
S.P. 486-0	Synthetic check (seed of 9 European brands pooled to furnish initial planting stock. 486-0 produced in New Mexico in 1948 by field overwintering from the same seed stock used for the production of 4-5-0)
S.P. 488-00	Synthetic variety (seed stock composed of US216MS x 225 and of a mixture of 5 inbred lines as pollinator)
US 216 x 225 (Acc. 1122)	Commercial seed (WC No. 8312)
US 226 (Acc. 1119)	An increase of 4713-0 (WC No. 8324)
H-125 (Acc. 1123)	From H. L. Kohls, Mich. Expt. Sta. (Mich. inbred (MS phase) x US 216)

[1] Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration.

Local	Supplied by cooperators. At Fort Collins, Ault, Longmont, and Fort Morgan, Colo., the local was Great Western C-304; at Torrington, Wyo., Holly 40249-0; at Rocky Ford, Colo., American 1; at Sugar City, Colo., US 215 x 216; at Mason City, Ia., and Stewart, Minn., American 3; at all other locations commercial US 215 x 216/3, supplied by F. & M. Beet Sugar Association.

Figure 1. Left: New black root resistant variety, 48B3-00 (strip 80′ long). Right: European commercial varieties (4-row plots, 20′ long).

The new variety is both black root and leaf spot resistant. Both diseases were serious in the experimental field at Plant Industry Station. The poor stand and weak growth of European varieties are largely because of black root. Loss of foliage in the check strip is the result of severe attack of *Cercospora* leaf spot. (Plant Industry Station, Beltsville, Maryland, September, 1949.)

The data on sugar per acre, root yield and sucrose are summarized in Tables 1, 2, and 3. In Table 4, data for particular varieties in the tests of 1949 are compared with data for previous years as obtained from the same or related varieties. In these tables the performance of U. S. 226 for the given year is taken as 100%.

Summary Table 1.—Acre yields[1] of gross sugar in agronomic evaluation tests: 1949

Location	Reported by	471802-00	471803-00	486-0	488-00	Acc. 1122 U.S. 216 x 225	Acc. 1119 (WC8324) U.S. 226	Acc. 1123 H-125	Local	LSD 19:1
Fort Collins, Colo.	J. O. Gaskill; J. A. Elder	5279	5170	5006	5244	5156	5214	5243	6332	386
Ault, Colo.	J. O. Gaskill; J. A. Elder	7717	7323	7555	6478	6685	7168	7496	7778	407
Fort Collins, Colo.	G. W. Deming; J. P. Kintzley	8090	7526	7578	7563	7228	7682	7931	8425	449
Longmont, Colo.	H. E. Brewbaker; H. L. Bush	7764	7697	8342	7167	6811	7508	8034	8423	560
Fort Morgan, Colo.	H. E. Brewbaker; H. L. Bush	7507	6909	6048	7565	7256	6921	7719	8905	635
Torrington, Wyo.	C. E. Cormany; D. F. Peterson	6885	6701	7103	6344	6149	6629	6217	6709	N.S.
Rocky Ford, Colo.	C. W. Doxtator	7580	6938	6725	7143	6610	7439	7015	7480	620
Sugar City, Colo.	Kenneth Meyers	4944	4717	3962	4605	5295	4809	5094	5475	766
Mason City, Iowa	C. W. Doxtator	4247	4569	4136	4247	3908	4082	4357	4265	257
Stewart, Minn.	H. W. Bockstahler; C. L. Schneider	5463	5642	4623	5830	5695	5372	6070	5330	196
Latty, Ohio	P. A. Reeve; G. Nichol (Lill)	6440	5906	5053	6118	6136	5847	6830	5410	426
Merrill, Mich.	J. G. Lill	7428	7078	5826	7646	8319	7374	8906	6832	673
Saginaw, Mich.	P. A. Reeve; G. Nichol	5248	4782	3926	5377	5307	5460	5146	5145	437
Sebewaing, Mich.	P. A. Reeve; G. Nichol	6718	6775	5748	6589	6724	6710	6498	6718	454
Chatham, Ont.	C. & D. Sugar Co.	6173	5937	5087	5743	5955	6160	6576	5735	720
Wallaceburg, Ont.	C. & D. Sugar Co.	4555	4503	4358	4392	4521	4698	4588	4571	523
	Mean	6377	6136	5692	6128	6110	6192	6483	6471	
	as % of U.S. 226	103.0	99.1	91.9	99.0	98.7	100.0	104.7	104.5	

[1] Given as 9 plot averages for Longmont, Fort Morgan, and Sugar City
All other tests given as 8 plot averages.

Summary Table 2.—Acre yields[1] of roots in agronomic evaluation tests: 1949

Location	Reported by	471802-00	471803-00	486-0	488-00	Acc. 1122 U.S. 216 x 225	Acc. 1119 (WC8324) U.S. 226	Acc. 1123 H-125	Local	LSD 19:1
Fort Collins, Colo.	J. O. Gaskill; J. A. Elder	18.44	17.97	18.50	17.66	17.43	18.12	18.70	20.79	1.35
Ault, Colo.	J. O. Gaskill; J. A. Elder	22.05	21.19	21.36	18.84	19.06	20.68	21.28	21.75	0.98
Fort Collins, Colo.	G. W. Deming; J. P. Kintzley	23.83	21.82	22.67	21.58	20.92	22.45	23.39	23.83	1.16
Longmont, Colo.	H. E. Brewbaker; H. L. Bush	28.82	28.11	30.16	26.37	24.29	27.93	29.58	30.92	1.71
Fort Morgan, Colo.	H. E. Brewbaker; H. L. Bush	23.71	22.49	20.39	22.73	21.75	22.04	24.35	26.30	1.85
Torrington, Wyo.	C. E. Cormany; D. F. Peterson	24.11	22.74	24.21	22.15	21.22	24.16	22.72	23.84	N.S.
Rocky Ford, Colo.	C. W. Doxtator	25.80	24.00	24.45	23.77	22.39	25.59	24.97	25.46	1.67
Sugar City, Colo.	Kenneth Meyers	15.20	15.06	13.75	13.98	16.54	14.55	15.95	16.17	1.90
Mason City, Iowa	C. W. Doxtator	11.43	12.33	11.45	11.26	10.35	10.92	11.44	11.17	0.66
Stewart, Minn.	H. W. Bockstahler; C. L. Schneider	15.55	16.29	13.57	16.18	15.81	14.94	17.03	14.73	1.40
Latty, Ohio	P. A. Reeve; G. Nichol (Lill)	20.90	19.09	17.15	19.32	19.26	18.79	21.91	17.86	1.31
Merrill, Mich.	J. G. Lill	21.51	20.99	17.75	22.12	23.62	21.77	26.38	19.67	1.71
Saginaw, Mich.	P. A. Reeve; G. Nichol	16.22	15.31	13.08	15.52	15.81	16.56	15.87	15.68	1.01
Sebewaing, Mich.	P. A. Reeve; G. Nichol	18.81	19.01	16.49	17.76	18.13	18.67	17.83	18.55	0.98
Chatham, Ont.	C. & D. Sugar Co.	18.15	17.75	15.37	16.55	17.04	17.60	19.17	16.84	1.84
Wallaceburg, Ont.	C. & D. Sugar Co.	13.76	13.56	12.87	13.35	13.48	13.96	13.64	13.89	1.50
	Mean	19.89	19.23	18.33	18.70	18.57	19.30	20.26	19.84	
	as % of U.S. 226	103.1	99.6	95.0	96.9	96.2	100.0	105.0	102.8	

[1] Given as 9 plot averages for Longmont, Fort Morgan, and Sugar City.
All other tests given as 8 plot averages.

Summary Table 3.—Sucrose percentages[1] in agronomic evaluation tests: 1949.

Location	Reported by	471802-00	471803-00	486-0	488-00	Acc. 1122 U.S. 216 x 225	Acc. 1119 (WC8324) U.S. 226	Acc. 1123 H-125	Local	LSD 19:1
Fort Collins, Colo.	J. O. Gaskill; J. A. Elder	14.30	14.36	13.53	14.86	14.79	14.36	13.99	15.20	0.46
Ault, Colo.	J. O. Gaskill; J. A. Elder	17.49	17.27	17.68	17.16	17.53	17.34	17.58	17.88	0.39
Fort Collins, Colo.	G. W. Deming; J. P. Kintzley	16.96	17.24	16.73	17.53	17.29	17.11	16.96	17.71	0.52
Longmont, Colo.	H. E. Brewbaker; H. L. Bush	13.47	13.69	13.83	13.59	14.02	13.44	13.58	13.62	0.55
Fort Morgan, Colo.	H. E. Brewbaker; H. L. Bush	15.83	15.36	14.83	16.64	16.68	15.70	15.85	16.93	0.53
Torrington, Wyo.	C. E. Cormany; D. F. Peterson	14.28	14.71	14.60	14.41	14.39	13.66	13.59	14.07	0.68
Rocky Ford, Colo.	C. W. Doxtator	14.59	14.43	13.70	14.97	14.74	14.52	14.01	14.69	0.61
Sugar City, Colo.	Kenneth Meyers	16.18	15.42	14.41	16.49	16.05	16.66	15.87	16.63	0.97
Mason City, Iowa	C. W. Doxtator	18.60	18.56	18.10	18.90	18.94	18.73	19.09	19.09	0.41
Stewart, Minn.	H. W. Bockstahler; C. L. Schneider	17.58	17.33	17.07	18.03	18.02	17.98	17.81	18.08	0.43
Latty, Ohio	P. A. Reeve; G. Nichol (Lill)	15.42	15.49	14.72	15.87	15.94	15.55	15.59	15.17	0.56
Merrill, Mich.	J. G. Lill	17.23	16.84	16.42	17.26	17.59	16.94	16.88	17.36	0.60
Saginaw, Mich.	P. A. Reeve; G. Nichol	16.16	15.58	15.02	17.34	16.79	16.51	16.19	16.34	0.68
Sebewaing, Mich.	P. A. Reeve; G. Nichol	17.88	17.80	17.41	18.59	18.52	17.98	18.19	18.11	0.55
Chatham, Ont.	C. & D. Sugar Co.	17.00	16.68	16.44	17.38	17.50	17.50	17.16	17.01	0.59
Wallaceburg, Ont.	C. & D. Sugar Co.	16.59	16.60	16.92	16.44	16.76	16.81	16.81	16.45	0.46
	Mean	16.22	16.08	15.71	16.59	16.60	16.30	16.20	16.52	
	as % of U.S. 226	99.5	98.7	96.4	101.8	101.8	100.0	99.4	101.3	

[1] Longmont, Fort Morgan and Sugar City given as 9 plot averages.
All other tests given as 8 plot averages.

Summary Table 4.—Comparisons of leaf spot resistant varieties with U.S. 226: Applicable data from tests of previous years are included. (Percentages are based upon performance of U.S. 226 in years indicated)

Description	Seed No.	Year	Number tests	Acre Yield: Gross Sugar Average	Gross Sugar As % of U.S. 226	Roots Average	Roots As % of U.S. 226	Sucrose Average	Sucrose As % of U.S. 226
				pounds		tons		percent	
US 226 (8 lines as F_1's)	451034-0	1947	17	4593	100.0	15.38	100.0	14.85	100.0
US 226 (Inc. 3-1834-00)	4713-0	1948	18	5013	100.0	15.71	100.0	15.86	100.0
US 226 (Inc. 4713-0; WC8324)	Acc. 1119	1949	15	6284	100.0	19.61	100.0	16.28	100.0
US 215 x 216 MS	4612-00	1947	17	4381	95.4	14.41	93.7	15.12	101.8
US 215 x 216/3	Acc. 1098	1948	18	4795	95.7	14.99	95.4	15.81	99.7
US 216 x 225	471804-00	1948	18	4782	95.4	14.42	91.8	16.45	103.7
US 216 x 225; WC 8312	Acc. 1122	1949	15	6164	98.1	18.70	95.4	16.63	102.1
Synthetic Variety	471802-00	1948	18	5052	100.8	15.78	100.4	15.91	100.3
	471802-00	1949	15	6473	103.0	21.21	103.1	16.23	99.7
US 216 MS + Lines "A" and "U"	471803-00	1949	15	6230	99.1	19.51	99.5	16.13	99.1
US 216 MS + 5 inbreds	488-00	1949	15	6230	99.1	19.01	96.9	16.60	102.0
H-125	Acc. 1123	1949	15	6575	104.6	20.55	104.0	16.22	99.6
Synthetic Check (European)	4-5-0	1947	17	4369	95.1	14.61	95.0	14.99	100.9
	486-0	1949	15	5808	92.4	18.63	95.0	15.80	97.1
From beet sugar companies	Local[1]	1947	17	4344	99.4	14.30	97.9	15.13	100.9
	Local[2]	1948	18	5118	102.1	16.05	102.2	15.86	100.0
	Local[3]	1949	16	6471	104.5	19.84	102.8	16.52	101.3

[1] In 6 tests in 1947 , US 215 x 216 was used as local variety.
[2] In 7 tests in 1948, H-125 was used as local variety.
[3] In 7 tests in 1948, US 215 x 216 was used as local variety.

Summary Table 5.—Summary of tests of 12 varieties of sugar beets conducted at Saginaw, Michigan, (Rader Farm), and Latty, Ohio, (Zielke Farm). Cooperation of F. & M. Beet Sugar Association. (Results given for each test as 8 plot averages)

Variety	Acre Yield								
	Gross Sugar			Roots			Sucrose		
	Saginaw Mich.	Latty Ohio	Average	Saginaw Mich.	Latty Ohio	Average	Saginaw Mich.	Latty Ohio	Average
	pounds	pounds	pounds	tons	tons	tons	percent	percent	percent
US 216 x 225	4392	6177	5285	11.54	20.29	15.92	19.01	15.23	17.12
US 216 MS x 225	3801	6748	5275	10.12	20.90	15.51	18.71	16.14	17.43
US 215 (4n) x P-S (2n)	4082	6204	5143	10.69	21.54	16.12	19.05	14.39	16.72
SP 4611-00, US 216 x Cer. Res. Inbr.	4235	6046	5141	10.82	20.14	15.48	19.66	15.02	17.34
Syn. Var. (WC 8321)	3950	6099	5025	10.58	20.84	15.71	18.71	14.65	16.68
Syn. Var. (471015-0)	4264	5861	5063	11.42	20.27	15.85	18.70	14.44	16.57
Syn. Var. (481800-00)	4775	6371	5573	12.69	20.29	16.49	18.85	15.68	17.27
Syn. Var. (481005-0)	3818	6041	4930	10.72	19.81	15.27	17.89	15.24	16.57
US 226 (WC 8324)	4947	6130	5539	12.72	20.13	16.43	19.61	15.24	17.43
48B3-00 (Bl. Rt. Res.)	4531	6549	5540	11.34	20.87	16.11	19.99	15.69	17.84
486-0 ("Syn. Ch.")	4479	5482	4981	11.83	18.51	15.17	18.96	14.81	16.89
H-125 (Acc. 1123)	4568	6977	5773	11.87	22.59	17.23	19.34	15.46	17.40
Diff. Req. for Sig.—Odds 19:1	707	439	427	1.96	1.12	1.10	1.03	0.59	0.59

Cercospora leaf spot was severe enough to permit readings to be made at Fort Collins, Fort Morgan, and Sugar City, Colo., Mason City, Ia., and Stewart, Minn. At all other places the disease was reported as absent, mild, or negligible in amount and no comparative readings were made by co-operators.

In two tests in which leaf spot was a factor, the local variety C-304 was significantly superior in yield of sugar per acre, but its leaf spot reading was not essentially different from other resistant varieties in the test. In three tests in which the susceptible European type read about "4," its yield was significantly below resistant types. The 1949 season, like that of 1948, was one in which leaf spot was not serious in many fields in which the tests were conducted. Synthetic check was not significantly below U. S. 216 x 225, taken as the highly resistant type, in yield of sugar per acre in 7 of the 11 tests which were without leaf spot attack. Again, as in previous reports, attention is called to the fact that when leaf spot is not a factor, Synthetic Check, produced by pooling seed of 9 European commercial brands and then making a straight increase of the seed stock, and later making a second increase without selection, often performed as well as U. S. varieties or those bred by beet sugar companies.

U. S. 226, produced by intercrossing (as F_1's) of 8 leaf spot resistant strains, has been taken as the standard of comparison. Aside from behavior of certain varieties used as locals in a limited number of tests, discussed later, U. S. 226, as an average of 16 tests, was exceeded only by H-125 and 471802-00. It was, as an average of all tests, about 8% superior to Synthetic Check, exceeding it in sugar per acre 12 out of 16 tests, of which 9 cases involved significant amounts.

This performance of U. S. 226 was in line with its performance in previous years in which it had been found superior to Synthetic Check by about 5%, as an average of all tests. It was about 15% superior when leaf spot caused severe damage to the susceptible variety.

The good performance of 471802-00, another synthetic variety made by combining 6 inbred lines, some of which are different from those utilized to produce U. S. 226, may be interpreted to reinforce the conclusion drawn from the performance of U. S. 226, namely, that highly productive varieties made from many desirable inbred lines, each possessing good or even moderate leaf spot resistance, may, as a general average, give greater returns than the more resistant varieties of narrower genetic base which sometimes are low in root yield.

The 1949 tests afford opportunity to appraise the performance of U. S. 216 x 225. On the average, it yielded 1.3% less than U. S. 226. In the Ohio, Mich., and Ontario tests where it can be compared with U. S. 215 x 216/3 in 6 tests, it was better 5 out of 6 times. The variety should be kept under test until further comparisons under severe leaf spot exposure can be given.

The local variety Great Western C-304 at Fort Collins (2 tests), Ault, Longmont, and Fort Morgan, Colo., showed significant increases of sugar per acre for the variety over U. S. 226. In the Colo. tests, 471802-00 is a better performer than U. S. 226 when compared with C-304 or Synthetic Check (486-0).

In one test at Rocky Ford, Colo., American 1 was significantly superior to U. S. 216 x 225, and Synthetic Check. In the test at Mason City, Ia., American 3 was significantly better than U. S. 216 x 225, but not any other variety in the test. At Stewart, Minn., it was significantly better than Synthetic Check, not different from 2 other varieties in the test but was significantly exceeded by 4 other varieties in the test.

In 6 tests in the humid area, H-125, supplied by H. L. Kohls of Mich. Expt. Sta., was significantly better than U. S. 226 at Latty, Ohio, but not significantly different elsewhere. Compared with U. S. 215 x 216/3 used as local variety, it was superior significantly at Latty, Ohio, and Chatham, Ont., but not so elsewhere. H-125 was produced as part of the breeding research of the Mich. Agr. Expt. Sta. and is the result of hybridizing U. S. 216 with a male sterile phase of one of their inbred lines.

Two randomized block tests, 12 varieties replicated 8 times, conducted at Saginaw, Mich. (Elmer Rader farm), and at Latty, Ohio, (A. H. Zielke farm), by F. & M. Beet Sugar Association, have given additional information on U. S. breeding stocks. Averages from these tests are shown in Table 5. In these evaluation tests, Synthetic Check, U. S. 226, Commercial U. S. 216 x 225, and H-125 occurred and may serve to relate the results to the 8 x 8 series of tests. A triploid variety, 481806-01, was included and, as an average of the two tests, was below U. S. 226 by nearly significant amounts. However, there was wide discrepancy in the two tests, since at Latty, Ohio, the 3n variety did not differ significantly from the check. U. S. 216 MS x 225, as contrasted with Commercial U. S. 216 x 225, showed at Latty significant increase, but at Saginaw, Mich., a reverse relationship.

An outstanding variety in the tests is the black root resistant variety 48B3-00. This is the progeny of roots selected at Blissfield, Mich., in 1947 under conditions of severe black root exposure. It traces to 53 progenies obtained in a breeding investigation at Waseca, Minn., cooperative with the Minn. Agr. Expt. Sta. Stands were prevailingly good since black root was not serious. Hence, performance of the variety in the 12 x 8 tests is essentially an index of its productiveness. The variety did manifest very definite resistance to leaf spot attributable to the fact that the progenies involved came almost exclusively from U. S. leaf spot resistant types. As an average of the two tests, it was equal to U. S. 226. In the Saginaw test, it did not differ significantly from the check. In the Latty test, its superiority to U. S. 226 approached significance.

Special attention is called to this variety because of its showing under conditions of combined black root and leaf spot exposures at Plant Industry Station, Beltsville, Md., and under severe black root exposures at East Lansing, and Blissfield, Mich., and at Waseca, Minn. Its superiority in resistance to other varieties with which it was compared leads to immediate steps being taken to increase the seed supply, looking to the eventual release of the variety for use in the affected areas.

A Convenient Method for Preserving Sugar Beet Pulp for Analysis

CHARLES PRICE AND JAMES M. FIFE[1]

Introduction

In sugar beet improvement work breeding for resistance to specific diseases is important. It is necessary to conduct the tests in the areas in which the diseases occur. Agronomic tests, therefore, frequently are made at considerable distances from the sugar factory or from the research laboratory, and usually facilities are not available for setting up a temporary laboratory for the immediate analysis of the samples of sugar beet pulp to determine percentage sucrose and apparent purity coefficients. Furthermore, air temperatures may be unfavorable for obtaining accurate results in the absence of facilities for controlling temperature.

These conditions emphasized the need for a dependable method of preserving pulp from sugar beets grown on experimental plots until the samples could be transported to a well equipped laboratory for analysis at some later period. On the basis of exploratory tests in 1937 the method of storing pulp described in this paper has been used at the U. S. Sugar Plant Field laboratory at Riverside, California, whenever it has not been feasible to analyze the pulp at once. Other sugar beet research workers familiar with our results report that they have found the method of storing sugar beet pulp suitable for their purposes.

Methods and Results

In 1937 preliminary experiments were conducted to determine changes occurring in the sucrose percentage and coefficient of apparent purity of sugar beet pulp frozen immediately after sampling the beets. Strong evidence was obtained from sucrose analysis that little or no change occurred during storage of the pulp but in this test changes in reducing sugars were not determined.

In 1948 more extensive tests were conducted in which sugar beets grown at Brawley and Riverside, California, were used. The purpose of using beets from two sources was to determine whether or not the pulp from beets of high sucrose content grown in the Imperial valley would respond differently under storage conditions than pulp from beets of relatively low sucrose content grown at Riverside, California. In the respective comparisons of fresh with stored pulp from beets grown at the two locations it was found that there were no differences in responses in the two lots. Time was not available for making complete analyses of pulp from both lots; therefore, only the beets grown at Riverside were used for critical tests over a prolonged period of storage.

The plan of experiment followed was to select 20 beets free from disease and of uniform size from variety U.S. 56 grown in the experimental

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plot at Riverside. The beets selected were washed free of soil particles and the tops removed at the lowest leaf scar. The entire beet was then passed through a multiple rasp such as is used by the beet sugar industry. The mass of finely divided pulp was mixed thoroughly by an electrically operated

Table 1.—Changes in Sucrose, Reducing Sugars, Dry Matter, and Apparent Purity Coefficient of Sugar Beet Pulp Stored below 8° F.

Date analyzed	Period stored	Sucrose (fresh basis)	Reducing sugars (fresh basis)	Dry matter	Apparent purity coefficient
	Days	Percent	Percent	Percent	
9-15-48	0	15.7[1]			87.9[1]
9-16-48	1		0.12	21.62	
			0.12	21.02	
9-24-48	9	15.7	0.15	21.00	
		15.7	0.17	21.02	
9-28-48	13	15.7			
		15.7			
9-29-48	14		0.16	21.26	
			0.13	21.21	
10- 1-48	16	15.7	0.12	21.46	
		15.6	0.13	21.20	
10- 7-48	22	15.6	0.13	21.10	
		15.7	0.14	21.19	
10-15-48	30		0.14	21.35	
			0.14	21.45	
10-18-48	33	15.7			
		15.7			
11-10-48	56	15.7	0.13	21.10	87.9
		15.7	0.14	21.15	87.9
12-10-48	86	15.7	0.12	21.10	
		15.7	0.12	21.15	
1-14-49	121	15.7	0.16	21.25	
		15.7	0.16	21.25	
12- 6-49	443	15.6	0.20	21.30	
		15.7	0.21	21.30	

[1] Mean of 10 determinations.

mixer which introduced a considerable amount of air into the pulp during the mixing process. A number of small sample bottles with tight fitting lids were filled with pulp. These sample bottles held approximately 80 grams of mixed pulp. As a check on the uniformity of the pulp and for an accurate determination of the percentage sucrose in the pulp at the beginning of the storage period, the pulp in each of 10 bottles was sampled

separately for sucrose and purity. Sucrose percentages and total solids by refraction were determined by the one-solution method as devised by Bachler[1]. Extraction of sucrose was by the cold water digestion method of Krueger as modified by Sachs Le Docte.

To determine the reducing sugars, twenty grams of pulp were washed into a 200-ml. Kohlrausch flask with distilled water. One drop of caprylic alcohol was added to break the froth which formed when vacuum was applied to remove the air worked into the pulp during mixing with an electrically-driven mixer. Sufficient neutral lead acetate was added to clear the extract before the volume was adjusted. The extract was filtered clear, then deleaded with sodium oxalate and again filtered. The cuprous oxide was precipitated using an official method[2] and titrated with potassium permanganate using ferrous phenanthroline as indicator. Hammond's revised table was used when calculating the amount of invert sugar percent.

The bottles of pulp were stored in a cold storage unit in which the temperature was maintained at approximately —5° F. for the first 130 days. For the remainder of the period the samples were stored the temperature was maintained below 8° F.

Two or three bottles were taken at random from the cold storage unit on each of the sampling dates shown in Table 1. The pulp was allowed to thaw and the entire contents of the bottles were removed and mixed thoroughly before duplicate samples were weighed out for analysis. The uniformity of the dry matter determinations indicates that the thorough mixing and the introduction of air into the pulp during the process avoided serious separation of juice from the pulp while it was being prepared for storage or while samples were being weighed out. The sucrose remained unchanged in the pulp for a period of 443 days, and reducing sugars remained nominal in amount. The coefficient of apparent purity was determined on samples after 56 days of storage and there was no change.

Summary

Critical tests were conducted in 1948 to determine the effect of storing sugar beet pulp in a frozen condition for analysis later. In these tests, twenty beets were selected and prepared for sampling. The beets were passed through a multiple rasp such as is used by the beet sugar industry. A portion of the pulp was analyzed immediately and the remainder was stored at a temperature below 8° F.

These tests showed that no loss in sucrose and no significant increase in reducing sugars occurred in the samples stored for 443 days. The coefficient of apparent purity was determined on the samples after 56 days of storage and there was no change. It was found to be highly important to remove all of the thawed pulp from the container and to mix it thoroughly before samples were removed for analysis. If sufficient air is incorporated into the pulp during the process of mixing, the separation of the juice from the pulp apparently is avoided.

[1] Bachler, F. R. Facts About Sugar, 28: 420-423. 1933.
[2] Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists, 6th Ed. 1945.

Planting and Thinning

The Extent of Sugar Beet Emergence Studies at Colorado A & M College

R. D. BARMINGTON[1]

Since March, 1946, a total of 334 planter treatments, to study the effect of various equipment on beet seedling emergence, has been made by the Mechanical Engineering Section of the Colorado Agricultural Experiment Station in cooperation with the Beet Sugar Development Foundation and the U. S. Department of Agriculture. With few exceptions each treatment was replicated six times to reduce experimental error as far as possible. Every advantage was taken of variation in soil, moisture, climate and time of year to gain as much knowledge as possible from the different equipment. Plantings have been made from southern Colorado to the northern boundary of Wyoming and in other parts of Colorado, Nebraska and Wyoming. Planting dates in this area have extended from March 20 to July 26, the latter date being much later than any commercial planting could be made, but it did give some very interesting results on emergence during hot weather when it was necessary to supply moisture by irrigation.

During this time more than 75 mechanical devices and combinations have been used, not to mention more than 50 chemical, hormone and fertilizer treatments applied to the seed, designed to improve viability and stimulate early plant growth. As the experiment has progressed, only those devices and techniques which have fallen in a bracket equal to or better than the check were used for further testing. It has been felt that if a device showed an increase in seedling germination under some conditions but was never poorer than the check under other conditions that definite progress had been made. This system has eliminated a high percentage of the devices tested but has given some assurance that those continued in the test definitely have some merit. Some equipment has been continued in the tests for two or three years because, under the first set of conditions, good results were obtained as compared to the standard check planter. In all these tests the standard check was a commercial horizontal plate planter of the precision type with double disc furrow opener and cast iron, deep concave press wheels set ¾ of an inch apart.

As already stated the work was done in the semi-arid area of the Rocky Mountain states where sugar beets are grown under irrigation. The findings here may not be applicable to conditions of heavier rainfall or in West Coast fields where heavy freezing does not occur to improve the quality of the seedbed. In the mountain area it is seldom if ever necessary to plant when the surface of the field is wet enough to stick to the furrow opener or press wheels. Normal precipitation is heaviest in the spring months which is an aid to germination. However, rain or snow even at this season is not dependable as proven by one of the tests which was planted in five inches of dry soil and received no rain for five weeks after planting. In the heavier rainfall areas it might be necessary to provide scrapers for some devices. This has been kept in mind, however, in the design of all equipment and in some cases such as the pneumatic rubber press wheel there would be less danger from sticking soil than in the conventional iron wheel. Some cloddy fields similar to seedbed condition in parts of California have been encountered and in 1949 a device which produced top results in good seed-

[1] Associate Research Engineer, Colorado Agricultural Experiment Station, Colorado A & M College, Fort Collins, Colorado. Scientific Journal Series No. 318.

bed conditions failed to show substantial improvement in the cloddy field.

Apparently the ideal condition, as indicated by this series of tests, is first of all good cultural practices in crops preceding the beet crop which will enable the farmer to prepare a uniform, firm seedbed smooth and free of trash and weed seed, with sufficient moisture to produce germination. The planting equipment should place the seed uniformly in the bottom of

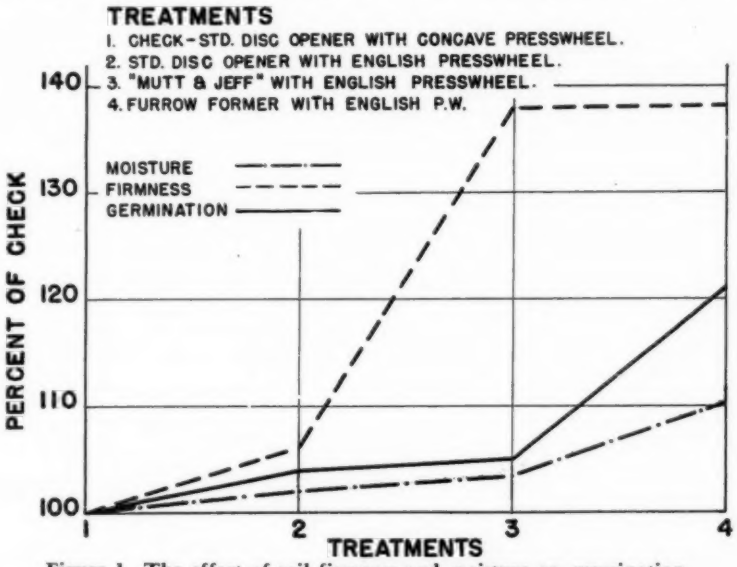


Figure 1. The effect of soil firmness and moisture on germination.

the furrow which has been packed below the seed by the furrow opener or in some other manner and the furrow closed over the seed by presswheels which will pack soil tightly in the seed zone, leaving the surface mulched to prevent crusting. Tests have shown that when these conditions are met good germination results, but it has been very difficult to meet these requirements in the wide variety of field conditions encountered.

Regardless of the equipment used to accomplish the desired results, certain standards must be met. The device must not disturb the seed pattern or interfere in any way with the process of placing seed in the ground, as was the case when a stream of water was introduced through a special tube on top of the seed. The presswheel must not leave a smooth glazed surface which will bake and crust. Any projection on the packing device must not extend so far into the ground that the soil is loosened as the wheel moves on down the row. The presswheels must not leave the row so the plants come up in a small ditch since such a condition does not lend itself to mechanical thinning or weed control practices. A small ridge in the row is not desirable because the extra depth of soil over the seed may cause the plants to be weakened before they come up.

The outstanding device in this series of tests was the Furrow-Forming wheel which presses a "V"-shaped furrow into the ground 1¼ inches deep with a small shoe following immediately behind the wheel to hold the furrow

open while the seed is being deposited. When this unit was used with any good presswheel design, it gave good results.

Although several devices have shown from 5% to 15% increased germination over the standard check, this is not good enough to take full advantage of the potential sprouts available. The Furrow Former has given 50% increase in many instances and has, in some cases, produced as much as 100% more plants per 100 inches than the check. Even in late summer plantings where it was necessary to irrigate for germination the Furrow Former produced 56% more plants from the same seeding rate. *Seeds planted with this unit have always germinated faster,* making it possible to see the row plainly before plants from other units could be seen at all.

Pneumatic rubber presswheels have given variable results but the experience of 1949 indicates that perhaps most of the rubber wheels used have been of too large a cross section, which gave a low unit pressure on the ground. In general a single rubber presswheel which ran directly over the row gave better results than two wheels set to run on either side of the row, running either in a vertical plane or at an angle. A single wheel 14 inches in diameter having a solid rubber tire of an approximate "V" cross section running directly on the row gave a surprising increase in germination in the 1949 tests. The chief disadvantage was that the beets came up in a small furrow which made mechanical thinning or even close cultivation impossible when the plants were small. This difficulty might be overcome by dragging something to fill this furrow but no tests have been made to check the theory.

The English-type presswheel has given consistent improvement of 10% to 15% over the check. The English-type presswheel consists of two 3/16-inch steel plates 12 inches in diameter spaced 5 inches apart. Running between the plates on the periphery, 1/8-inch steel rods are placed at 1½ inch intervals, forming a cage like structure. Inside the cage is a piece of steel shafting 4 inches in diameter and 4¼ inches long which rolls freely by gravity to the bottom of the cage. This device packs the soil around the seed and leaves the surface in a very nice mulched condition.

Some type of toothed projection placed between the two halves of the standard concave presswheel running directly on the row has also given consistent improvement in germination. The projections should be made so they are self cleaning and should not extend more than ¾ of an inch beyond the rim of the wheel.

It is recognized that not all the possibilities for mechanical changes to improve germination have been investigated but, of those which have, some have shown consistent improvement. These and new ideas will be continued in future tests as time and facilities permit.

Table 1.—Combined results of part of the presswheel equipment tested at Colorado A & M College during the four years 1946 through 1949.

No. Tests	No. Replications	Description	% Emergence
32	147	Deep concave presswheels (check)	100
43	260	Furrow Forming wheels	128
9	54	"V" cross section rubber (single wheel)	128
15	90	Old flat rim presswheels	120
9	54	Pneumatic rubber (two wheels beside row)	117
12	72	Toothed projections between presswheels	115
10	52	Multiple wedge shaped presswheels	113
20	120	Pneumatic rubber (single wheel over row)	113
8	38	Deep concave set together	112
19	74	English presswheel	110
10	48	Sishc Presswheels	95

"Getting Stands"

O. A. HOLKESVIG[1]

With the introduction of segmented seed it became evident that uniform stands were difficult to obtain and it was the opinion of many that most of the trouble was due to the seed. We have learned through experience and study of our problems that securing satisfactory stands from processed seed depends as well on a number of other factors which were given little or no consideration when processed seed was first introduced. We have learned that land preparation, seed bed preparation, seed treatment, the size of seed in relation to size of planter cell, rate of seeding, depth of planting, type of planter and rate of travel, condition of seed plates, and operation of planter furrow opener and press wheels all have equally important parts along with seed in producing desired stands.

Land and Seed Bed Preparation

In the Red River valley in Minnesota and North Dakota, where an annual average rainfall of less than twenty inches is depended upon for moisture, land preparation the prior year is necessary in order to store additional moisture and preserve it for the beet crop. Therefore, all land leveling and deep tillage is completed in the fall in order that a good seed bed may be prepared in the spring by only a shallow cultivation and the liberal use of a harrow. This method holds moisture close to the surface for germination and leaves a coarse mulch which will reduce wind erosion.

Planter Cell Fill

The irregular shape and projecting corners of segmented seed prevented seed segments from entering the round seed cell in the seed plate of the planter, resulting in a low rate of cell fill and low seeding rate. Change in method of processing seed to decortication has resulted in seed more uniform in size and roundness, which enters the planter cell more readily. In recent tests conducted by our organization, cell fill was increased by 11 percent by using decorticated seed as compared to standard segmented seed. It was also ascertained that the tolerance once thought ample to accommodate the irregularity of seed was too limited, and instead of allowing 1/64-inch tolerance a 2/64-inch tolerance is now allowed between the size of seed and size of cell, which further increased the cell fill by about 10 percent. Worn seed plates are another item which should be given attention, as badly worn places will reduce the cell fill 3 to 4 percent.

Seed Treatment

Damping-off disease is another cause of reduced stands. The fungicides available do not offer a one hundred percent prevention of this disease, but the Ceresan treatment which up to the present time has been used more extensively than any other fungicide in this area has under normal conditions resulted in increases of from 8 to 10 percent in stands from treated seed as compared with untreated seed plantings.

[1] Manager, American Crystal Sugar Company, Moorhead and East Grand Forks, Minnesota.

Rate of Seeding

The theory advanced by some in the areas where beets are grown under irrigation, that a low rate of seeding will eliminate hand thinning, has not proved out in practice in the Red River valley. It is a well known fact that due to less favorable germinating conditions field germination of seed is always less than the laboratory germination. With this known loss of germination, a uniform stand is not attainable when using a low seeding rate. On 18-inch row widths an 8-pound per acre seeding rate (having 41,000 to 43,000 seed units per pound) will give approximately one seed every inch in the row. This distribution in the row has under normal or even adverse conditions permitted leaving narrow blocks of from one-inch to one and one-half inch size for the cross-cultivation work, and with a fairly severe use of the finger weeder still leaves from 15,000 to 20,000 beet-containing blocks per acre, which is ample from which to work out a good stand under the conditions existing in the Red River valley, where, as previously indicated, a limited amount of rainfall is had.

Planter Performance

A precision drill equipped with the correct size of cells, and with plates in good condition, and using the proper size of seed, distributes seed evenly in the row. We have found that the lower the drop from seed can to furrow, the less bunching obtained, together with better distribution. It has further been proved that seed cans should be kept close to two-thirds full in order to maintain uniform rate of seeding. Speed is another factor which governs cell fill and seeding rate. In several field tests it was found that increasing the planting speed from two and one-half miles per hour to three miles per hour reduced the seeding rate by more than 6 percent.

Depth of Planting

In recommending the depth seed should be planted, the weather conditions which may follow planting must be taken into consideration. Not knowing what the weather may be, we must prepare for both favorable and adverse germinating conditions. There is no question that, with ample moisture and cloudy weather, which will permit moisture to remain close to the surface, very shallow planting is preferable. In the event, however, of high temperatures and high winds, moisture will be dried out to an appreciable depth, and then light rains may start germination and the heavy evaporation will leave the young roots stranded in dry soil with resulting loss of stands. Too deep planting will find the young seedling dying either from disease or from having exhausted the food supply before reaching the surface, with a consequent reduction in stand. It has been found in our area that a one and one-half inch depth seeding will afford protection in both directions.

The furrow openers should be checked after each year of service. As the disc openers wear the diameter of the disc becomes less, and the depth of planting is reduced accordingly.

At this point the condition of the seed bed has to be re-examined, as press wheels will form a deep trench in loose seed beds and a heavy rain at this time will level off the surface and increase the depth of the seed

according to depth of the trench. Therefore, a firm seed bed is also essential from the standpoint of securing a uniform depth of planting.

Furrow Opener

The furrow former and shoe developed by the Beet Sugar Development Foundation was used this year on an experimental basis in the Red River valley with a definite increase in emergence in comparison to the conventional type of furrow opener. On twenty 100-inch lengths of row, stand counts made after the new furrow opener showed that an average of 103.45 seedlings per 100 inches of row were obtained. Following the conventional type furrow opener, on twenty stand counts 84.2 seedlings per 100 inches of row were obtained, or an increase in emergence of approximately 19 percent. Some trouble was experienced, however, in moist soil sticking to the furrow-forming wheel and to the shoe opener, and also clogging of the tube. With addition of a scraper and a change in shoe we believe this difficulty will be corrected.

The English press wheel introduced by the Foundation this past season has proved superior to the standard type of press wheel. Comparisons of twenty random counts on seedling emergence when the English press wheel was used averaged an even 100 seedlings per 100 inches of row, whereas an average of only 84.2 seedlings per 100 inches of row were obtained when the standard type of press wheel was used. For efficient operation of the English press wheel, the ground speed of planter travel should not exceed two and one-half miles per hour. Operating at higher rates of speed caused the floating weight to rotate with the cage. This objection will no doubt be corrected by further improvements.

In the Red River valley a problem is experienced in bringing late plantings to stand. This is due to high temperatures and occasional high winds which draw off the surface moisture to a depth lower than the planted seed. As a means of overcoming this condition, ridge covering has been resorted to with considerable success. On a majority of fields which have been ridge-covered we have found that soil moisture rises close enough to the surface for full germination of seed. On other fields where soil moisture has receded ridging did not bring it in contact with beet seed to benefit germination of seed, but weed growth was controlled and it was not necessary to replant these fields. Growers must be cautioned to check their fields very carefully each day and remove the covering as soon as possible after it has served its purpose, making certain that all of the covering is removed and no part of the ridge is allowed to remain.

While there are certain hazards such as a period of wet weather or a heavy downpour of rain in connection with the use of this method for improving germination and field emergence of seedling plants, the risk is justified because of providing a means of weed control and bringing moisture to the surface by capillary action for germination until additional moisture is received in the form of rain.

The suggestions and methods outlined in this paper, with the exception of the furrow-forming unit and the English press wheel, have proved out in practice on thousands of acres in the Red River valley, and their use has produced such favorable results that we feel stands are no longer a serious problem but are simply a matter of employing on a large scale correct methods and means which we now have at our disposal.

Physical Factors of the Soil Affecting Beet Seedling Emergence[1]

R. D. BARMINGTON[2]

There are, perhaps, many factors influencing the germination of sugar beet seed which have never been recognized and still others which are known to exist but are not fully understood. Experience has shown that firmness of the seed bed is vitally important, that the shape of the furrow or the manner in which it was made has an influence on seedling emergence. Everyone recognizes that a certain amount of moisture is essential to germination of any kind of seed, yet very little is known definitely about these relationships. In the past it has been common practice for farmers or fieldmen to walk over a seed bed and judge the condition of the seed bed by the "feel" or by the depression left by the heel of the shoe. Such practice requires a great deal of skill and years of experience to be of any real value and has the distinct disadvantage of not being measurable in units which can be recorded or communicated to interested persons in other communities.

In some cases devices intended to improve germination have failed to give the expected results, which indicates that some of the conditions required by nature to produce germination have not been met. In order to get more accurate information on what happens in the area near the seed, the mechanical engineering section of the Colorado A & M Agricultural Experiment Station, cooperating with the Beet Sugar Development Foundation, has used two tools to obtain fundamental data which may help to explain some of the difficulties. A soil firmness probe for determining soil density and a soil sampler for taking samples in the seed zone for subsequent moisture analysis were used to study soil and moisture conditions.

The idea of using a soil probe to determine soil firmness is not original, but the probe used in these tests was designed for simplicity of operation and easy carrying in the field. The probe is a flat disc one-half square inch in area which is forced into the ground by hand pressure. A compression spring inside a telescoping tube which has been calibrated in pounds provides an easy means of determining the pressure being applied. The probe extends through a large flat plate which rests on the surface of the ground as the probe is pushed down. There is just enough spring tension between the plate and probe to hold the plate in place for reading when the probe is removed from the soil. Graduations on the probe indicate the depth of penetration. This depth along with the spring pressure applied enables the operator to calculate the force required to displace one cubic inch of soil. The entire instrument resembles a walking cane and weighs about two and one-half pounds.

The probe was used following four types of furrow opener and press wheel combinations in ten farmers' fields in northern Colorado on soils

[1] Scientific Journal Series No. 319, Colorado A & M Agricultural Experiment Station, Colorado A & M College, Fort Collins, Colorado.
[2] Associate Research Engineer.

varying from sand to heavy adobe. The tests were made in the undisturbed field and again directly in the row after the planter had passed over the ground. The combined results of these tests are shown in Table 1. Each figure represents the average of ten tests and the average figure for each treatment represents 100 individual tests.

In this test four different planter units were mounted in a four-row planter frame. Treatment one has been called the "Mutt and Jeff" arrangement in which a 7¼" diameter wheel with a ⅜" high ridge in the center of the rim was used to form a shallow groove in the soil. This was followed by a very small shoe on the end of the seed tube which deposited the seed in the groove made by the small wheel. Following the shoe was a larger wheel 12½" in diameter with a ridge 1¼" high in the center of the rim

Table 1.—Combined Resulted of Soil Firmness Test[1]

Farm	Field Before Planting	Treatments after planting (Tests made directly over the row)			
		1	2	3	4
Schwindt	25.7	48.6	42.0	37.9	46.4
Schmier	18.3	63.5	41.4	43.2	63.1
Neubauer	36.5	81.6	47.8	53.4	56.6
York	32.2	63.7	50.1	51.0	58.6
Pitcher	22.1	46.4	35.2	39.5	47.5
Weichel	40.3	64.1	46.6	45.4	89.6
Knotwell	16.9	45.8	24.5	23.7	39.7
Morgan	22.4	43.9	29.9	37.2	42.7
Lohrey	34.1	48.0	35.1	46.8	51.4
Schilling	36.6	59.3	56.7	57.1	49.5
Total	285.1	564.9	409.3	435.2	565.1
Average	28.51	56.49	40.93	43.52	56.51

Difference required for significance—5% level—6.53
Difference required for significance—1% level—8.81

[1] Figures represent force in pounds required per cubic inch of soil displaced by a one-half square inch soil probe.

running directly on the seed to push the seed down to planting depth. This wheel was in turn followed by an English-type press wheel. Treatment 2 was the standard check consisting of a commercial John Deere No. 64 double disc opener with a standard deep concave press wheel. Treatment three was the same as treatment two except that an English-type press wheel was used instead of the standard deep concave type. Treatment four was a furrow former wheel 11½" in diameter with a "V"-shaped ridge 1¼" high in the center of the rim which pressed a furrow in the ground. A small shoe close behind the wheel held the furrow open as the seed was deposited in the bottom of the furrow. An English-type press wheel then closed the furrow and packed the soil over the seed.

Soil samples for moisture analysis were taken on the same planter treatments, but due to the extensive nature of such a sampling project only five farms were used. Sixteen cubic inches of soil were taken in the seed zone by taking a section of soil two inches wide, two inches deep and four inches

lengthwise of the row. Samples were taken from two to three days after planting to show the effect of moisture movement after using various planting treatments. The percent moisture shown in Table 2 was determined by standard laboratory moisture technique.

Results of seedling emergence shown in the first half of Table 3 give a rough comparison with the farmers' planting. Direct comparison with the farmers' planting could not be made because his seeding rate could not be checked. The second half of Table 3 shows direct comparisons between treatments with differences required for statistical significance.

Table 2.—Average Soil Moisture Percent on Five Farms[1] [2]

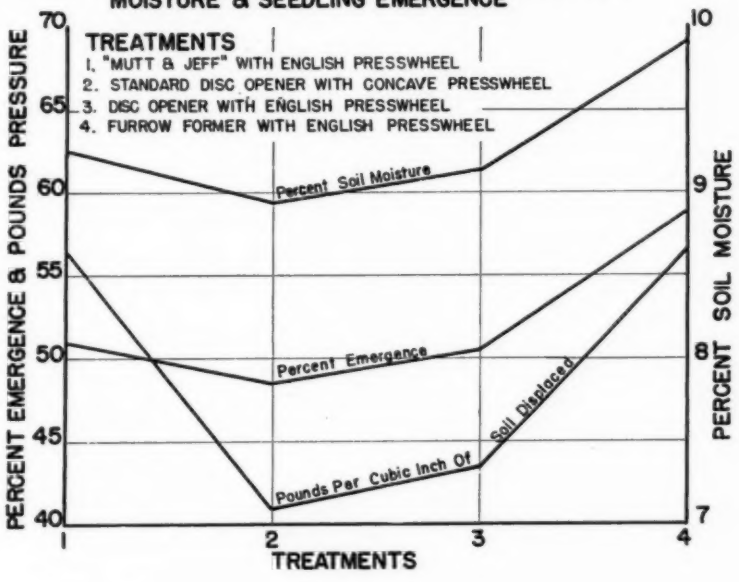
Farmer	Treatments			
	1	2	3	4
Pitcher	8.6	9.5	9.6	13.1
York	8.4	8.2	10.1	7.9
Neubauer	8.1	8.0	8.6	9.6
Weichel	9.9	9.6	8.2	8.9
Knotwell	11.3	9.4	9.2	10.1
Average	9.26	8.94	9.14	9.92
Differences not statistically significant				

[1] Average for top two inches of soil.
[2] Analysis made on wet basis.

The correlation between soil moisture, soil firmness and seedling emergence is shown graphically in Figure 1. There was a striking similarity between the shapes of the curves, which indicates the relation of the three factors. Although the percentage of moisture in the soil appears low, ranging from 8.94 to 9.92, the percent increase produced by the experimental equipment is 9.9%. Individual cases have shown increases in soil moisture as large as 22.4%. The amount of soil packing produced by the various treatments was apparent by the wide range of figures representing pounds per cubic inch of soil displaced by the probe. The range of these figures was from 40.93 pounds to 56.51 pounds. The average of all ten farmers' fields before passing over with any kind of planter equipment was 28.51 pounds per cubic inch as shown in Table 1. The poorest planting equipment increased this figure by 43% and the best planting equipment by almost 100%. The difference between treatments 2 and 3 was due to the English-type press-wheel. Theoretically, the difference between treatments 1 and 4 should be slight because both treatments used a furrow-forming wheel. Actually the difference was considerable, as shown, because of functional troubles with treatment 1. In replicated plots on nearly ideal seed bed conditions treatment 1 was best of all, but in farmers' fields, where the texture of the seed bed tended to be lumpy or cloddy, the small wheel making the shallow furrow in which to deposit the seed did not produce a definite groove to hold the seed in line and a high percent of the seeds was not pushed down to planting depth by the second wheel. This wheel arrangement is not thought to be as universally acceptable to all field conditions as treatment 4, but appeared to have enough merit to warrant further study.

It was evident from the experience of two years that planting equipment which pushes a furrow into the ground to deposit the seed produced more plants from a given amount of seed than any other type of equipment even when the field was irrigated after planting. Just why this should be is not known. It is quite conceivable that a seed bed could be rolled and packed to produce a firm condition which would facilitate movement of water to the surface by capillary action. In this case movement of water

FIGURE I. THE RELATION BETWEEN SOIL FIRMNESS, SOIL MOISTURE & SEEDLING EMERGENCE



to the surface and evaporation from it would be spread uniformly over the field. Use of the "V"-shaped furrow former to press a groove into the soil and depositing the seed in the bottom of the furrow thus formed seemed to cause capillary action to bring moisture to the point where the seed was and to continue to bring moisture to this point during the germination process. As the seedling develops the firm soil under the seed provides a good place for the plant root to establish itself.

Even with the best techniques and the best planting equipment known, preparation for a good stand of sugar beets must start the year before or even two or three years before the beet crop is to be planted. Good general cultural practices are just as important as the proper equipment or good

Figure 2. This soil firmness probe was used to determine soil density. The probe is a flat disc ½ sq. in. in area which is forced into the ground by hand pressure. A compression spring inside a telescoping tube which has been calibrated in pounds provides an easy means of determining the pressure being applied. The probe extends through a large flate plate which rests on the surface of the ground as the probe is pushed down. The author is shown here holding it.

Table 3.—Beet Seedling Emergence in Ten Farmers' Fields.

Farmer	Farmers' Planting	Average No. Plants Per 100 inches of Row Treatments			
		1	2	3	4
Knotwell	35.0	61.9	75.1	67.1	70.7
Lohrey (1st count)	66.9	59.4	49.4	49.0	64.3
Lohrey (2nd count)	67.9	59.7	55.0	58.4	68.4
York	58.1	44.0	50.2	41.5	43.1
Morgen	59.9	45.8	38.5	35.9	37.3
Schwindt	29.3	44.6	24.5	36.9	43.3
Weichel	41.2	62.9	73.1	66.9	63.2
Pitcher	62.7	64.9	62.8	66.4	57.9
Neubauer	39.6	58.8	48.2	55.4	55.4
Schilling	48.3	63.6	65.8	59.7	60.7
Schmier	4.8	35.7	39.5	60.8	68.7
Average	46.7	54.7	52.9	54.4	58.6

Farmer	Percent of Potential Emergence Treatments			
	1	2	3	4
Knotwell	60.91	67.28	64.44	73.18
Lohrey (1st count)	54.85	46.70	45.60	64.33
Lohrey (2nd count)	55.13	51.99	54.35	68.43
York	44.02	45.31	38.62	44.22
Morgen	43.29	33.98	32.40	38.27
Schwindt	37.18	23.16	33.31	44.43
Weichel	57.64	63.59	63.73	67.74
Pitcher	60.39	56.68	62.77	60.44
Neubauer	55.58	51.22	53.20	56.84
Schilling	58.28	58.95	55.13	61.75
Schmier	33.48	36.76	54.88	68.73
Average	51.00	48.70	50.70	58.90

Difference required for significance—5% level—5.15
Difference required for significance—1% level—6.93

seed. If green manure or other organic material is continually being added to the soil it is more likely to produce a friable soil which will hold moisture and work down into a satisfactory seed bed. Fall plowing and other weed control measures are necessary in preceding crops to assist in controlling weeds in the beet crop. If a field is prepared for planting a beet crop, and weeds make it necessary to work the field again before planting, the chances of having enough moisture left to produce a good stand of beets are poor. The best planting equipment and techniques known can not compensate for a haphazard job of seed bed preparation. These experiments have shown that there is a correlation between the type of equipment used, the firmness of the soil after using various tools, the moisture held in the seed zone and the emergence of seedlings.

Two Years of Planter Testing

JAMES H. FISCHER[1]

The question "Are the Present Day Drills Adequate?" for planting our present day sugar crop has been a point of much debate between men of the sugar companies as well as representatives of the many implement manufacturers. Two lines of thought are encountered: (1) If present day planters were adequate, we would not have today's emergence and thinning problems, and (2) If beet seeds are more germinable, our methods of getting a stand are satisfactory, present day planters would suffice. The Beet Sugar Development Foundation has picked the first as a problem worth investigating with the thought of finding methods to improve present planting practices with the machinery which is already on the farms. By no means has the answer been found but some startling obsrvations have been made.

Before dwelling upon observations and results, a brief summary of the method of attack will be given. For many years the primary method of checking the seed pattern from any drill was to give it a "grease board" test which does not permit the movement of seed as in a furrow. The method most commonly used to obtain cell fill is to jack one wheel of a planter up, drive that wheel from an auxiliary motor and collect seed as it is discharged from the seed tube for weighing and analysis of the cell fill. The British have two rather elaborate photosensitive devices to check planter seed distribution. One charts, as a seismograph, each impulse caused by seed discharged from the tube. The other method registers on photosensitive paper with a movie camera (shutter removed) the actual path of each seed as the paper moves past it.

Deeming these methods not too satisfactory, the Foundation launched on a program to construct a planter tester rack which permits planters to be mounted stationary in a simulated ground furrow condition to move under the drill on an endless belt. Provisions were made to adjust plate speeds at any desired seeding rate and any probable speed of drilling as obtained in each case by the use of two P.I.V. variable speed drives. Drills without provisions for varying seeding rates were mounted so as to be driven from a ground speed sprocket.

A large variety of materials was tested to arrive at a condition which most nearly simulated furrow conditions. Asbestos cemented to V-shaped rubber sheeting sewn to cord rubber belts was the material finally selected to serve as a standard approximating soil conditions.

The method of checking the seed distribution in the furrow was identical with the method used to count stands in the field, using a 100-inch ladder and a stand count sheet. Presently thirty (30) 100-inch counts (250 feet) are deemed adequate for each analysis. Longer runs have been counted to show small differences which are statistically insignificant. During the life of the planter tester some 1,900,00 inches have been counted inch for inch. This is equivalent to approximately 30 miles.

[1] Engineer, Beet Sugar Development Foundation, Fort Collins, Colorado.

The method of checking cell fill is somewhat revolutionary since weighing of planted seed is eliminated. Cell fill is figured from the actual seeds which are counted in the simulated furrow, as we know from the setting the number of cells which has passed under the knock-out. The error of weighing grindings or ungerminable seed portions is eliminated. We have had opportunity to check one method against the other by collecting the seeds discharged from the tube in a container before they drop on the endless belt. This was done immediately subsequent to the counting method using the same seed, all conditions identical. The results are shown below in Table 1:

Table 1.—Comparison of Cell Fill Methods.

	Percent Cell Fill	
	Seed Count Method	Weight Method
Seed No. 1	100.17	106.38
Seed No. 2	98.63	104.34

Notice that with this particular seed the cell fill obtained by the planter tester method is in the order of 6% below the other methods. This 6% could be taken as a measure of grinding of the particular seed being tested. These figures were all compiled considering seed ball count, weights and actual distribution counts.

Our tests indicate to the amazement of all concerned that new plates give better cell fill than old plates. We have been able thus far only to theorize reasons causing better cell fill in new plates since the opposite seems most logical. Below are given comparisons of five identical seeds showing difference in cell fill between old plates and new plates.

Table 2.—Old and New Cell Plate Comparisons.

	Percent Cell Fill	
	Old Plate	New Plate
Seed No. 1		
8-9/64	77.26	94.79
Seed No. 2		
9-10/64	68.82	74.17
Seed No. 3		
6.4% 7-8/64; 46.9% 8-9/64; 46.7% 9-10/64	70.07	88.44
Seed No. 4		
15% 7-8/64; 45% 8-9/64; 40% 9-10/64	63.58	91.74
Seed No. 5		
25% 7-8/64; 70% 8-9/64	86.01	96.91

The effect of segmentation or decortication on cell fill seems to be of no significance since our results have indicated little trend of one over the other.

Table 3.—Effect of Segmentation or Decortication on Cell Fill.

	Percent Cell Fill	
	Segmented	Decorticated
Seed No. 1	87.57	84.41
Seed No. 2	96.56	87.47
Seed No. 3	92.71	92.43
Seed No. 4	89.27	89.17

Note that seed No. 2 shows a difference which cannot be overlooked. We are not prone to suggest that this variety of seed should be segmented rather than decorticated to obtain better cell fill. Tests have indicated that the same seed, from year to year, will not give identical results. Seeds seem to be extremely sensitive to processing methods. Dr. C. W. Doxtator[2] has shown in his tests that the method of driving his screens has materially affected size of seed separation, consequently affecting cell fill. The seed balls per pound within a specified size limit have not offered a means of determining the size of cells to be used. A low seed ball count, of course, means a greater percentage of the seed is large, and a high seed ball count a greater proportion is small. Dr. H. B. Walker[3] and associates, in 1945, completed an intensive study relative to the shape of seed varieties before and after seed processing. It seems logical, from his report, that seed shapes are important in their relation to cell fill and such, perhaps, offers explanation to the information tabulated in Table 4.

Table 4.—Effect of Seed Character on Cell Fill.

Plate	Seed No. 1	Seed No. 2	Seed No. 3	Seed No. 4	Seed No. 5
10/64			103.5	100.3	89.1
.168			113.3	110.5	95.0
11/64	103.3	105.1	111.6	104.7	95.4
.180			117.4	118.5	101.8
Seed Ball Count	49,700	46,800	44,997	48,997	38,102

Note: All seeds 7-9/64 decorticated (cans one-half full)

A large number of experiments carried out by many individuals has proven that speed of drilling materially affects cell fill and distribution. The Beet Sugar Development Foundation has continued this study as shown:

Table 5.—Speed Relation to Cell Fill.

Speed M.P.H.	1½	2	3	4	5
% Cell Fill	125.87	108.93	102.31	93.40	93.32

We have found that plates which give a cell fill of 95% to 100% based on planter tester results also distribute the seed to a more desirable pattern. Both above and below this specified limit a rather sharp decline from a desirable distribution is noticed. Many thousands of acres of sugar beets were planted in the year 1949 according to specifications given after tests on the planter tester. The results of these plantings have indicated that the planter tester has been valuable on a commercial basis for selection of the proper cell plate for a certain seed variety.

[2] Director of Experiment Station, American Crystal Sugar Company, Rocky Ford, Colo.
[3] Head, Division of Agricultural Engineering, University of California, Davis, Cal.

Yes, we might say our present day drills are adequate for planting our present day beet crop, if time is taken to select properly the correct plate which most satisfactorily gives the desired cell fill, keeping in mind the following:

1. **New plates give better cell fill than used plates which are worn.**
2. **There does not appear to be much difference in the performance of segmented or decorticated seed, provided the proper cell plate is used.**
3. **Performance of seed appears to be dependent upon seed shape or character and is not specifically related to the number of seed units per pound.**
4. **There is a definite limit on speed for each combination of seed and cell size.**
5. **Seed pattern is best within the 95% to 100% cell fill limits.**
6. **We recommend the use of all available facilities to pre-determine for each lot of commercial seed a plate which most successfully gives the most desirable cell fill at given field drilling speeds. The sugar beet grower will then have a good chance of planting the rate of seed which he has selected, if the proper adjustments are made.**

Adaptations for the Dixie in Down the Row Thinning

L. W. DeWALD[1]

Mechanization of the spring sugar beet crop has advanced quite rapidly in recent years but still poses many questions which we have yet to answer. Sugar companies have so thoroughly implanted in the growers' minds that single beets spaced at given intervals were so much to be desired that it is difficult to convert them to a program which might well be satisfied with 25% or higher double or even multiple beets to the hill. Many types of machines can more or less accomplish this end but the Dixie was used because it was available in greater numbers and immediately.

Two adaptations for the Dixie were made, one consisting of a weeding wheel featuring 18 ordinary side delivery rake teeth radiating from a hub and for use on beets when as small as the two- to four-leaf stage. A stub blocker was devised with eight spokes from a hub with 1¼" blockers welded to the end of the spokes. These were used when the beets had attained a larger size and could stand more severe treatment. The stub blocker was used on the plots at the Company's Lewiston, Utah, farm when the beets were in the 10-12 leaf stage. This stage was used as it was felt it was a time when growers get panicky and are apt to abandon the crop if hand labor is not available immediately.

Three plots were selected in the middle of a seven-acre field with 24 rows to the plot. At harvest the plots actually measured .267 acres each. Seven pounds of decorticated seed were planted to the acre.

Plot No. 1—Hand thinned, weeded and harvested.
Plot No. 2—Mechanically thinned with Dixie Stub Blocker over twice, long hoe trimmed, mechanically harvested.
Plot No. 3—Mechanically thinned with Dixie Stub Blocker over twice, one hoeing, mechanically harvested.

	Number beets per 100 Feet at harvest	Tons Per Acre	% Sucrose
Plot 1	65	25.93	15.8
Plot 2	95	25.53	16.16
Plot 3	178	23.20	17.06

The entire field exclusive of the plots averaged 23.46 tons per acre.

Plot No. 1 was handled at the regular thinning and hoeing rate which in this area was $12.00 for thinning and $4.00 for 1st hoeing. Sixteen dollars per acre was the entire labor expenditure at time of harvest.

Plot No. 2 was also paid at the prevailing wage rate of $12.00 and $4.00. The labor was asked to trim the beets so that not more than doubles were left in any one hill. The harvested stand contained 13% doubles and the labor cost at that time was $16.00 per acre.

Plot No. 3 was long handle hoed once at a cost of $4.00 per acre. In the hoeing the labor attempted only to reduce large clumps of multiple beets and at harvest many hills averaged three to five or six beets. The entire hand labor investment at harvest was $4.00 per acre.

[1] Agriculturist, General Office, the Amalgamated Sugar Co., Ogden, Utah.

Yield Studies of Mechanically Thinned Sugar Beet Trials in California

J. B. LARSEN[1], S. S. ANDERSON[1], A. A. ARMER[1]

During the spring of 1949 a series of experiments was conducted in an attempt to determine the effects of mechanical stand reduction on yields of sugar beets, and to provide a reasonably accurate answer to the question: "Does mechanical thinning depress yields?"

The actual method of mechanical thinning varied according to field conditions. Where stands of beet seedlings were excessively heavy or badly infested with weeds, the Eversman or Milton finger weeders were used. In the thinner and more regular stands, blocking was accomplished with Eversman, Milton or Blackwelder (experimental chemical spray) blockers.

It must be emphasized that the success of mechanical methods rested heavily on the judgment used in selecting equipment, methods, size of beet seedlings and condition of seed bed.

In order to evaluate the efficiency of these various devices, a number of trials was harvested both by hand and by machine.

Methods and Procedure

Two approaches to the problem were employed.

The first approach was to conduct replicated trials, the experimental design for which would yield results of relatively high significance.

The second approach consisted of a relatively large number of single strip treatments in commercial fields. These trials would put the mechanisms in the hands of practical beet growers, who would put mechanical methods on trial under a wide range of actual field conditions.

Replicated Field Trials

Two locations were selected for replicated field trials: one at King City, California, and the other at Spreckels, California. Three different thinning treatments were used: Hand, Milton weeder blocker and Blackwelder spray blocker. These treatments were replicated five times in strips throughout the field. The plots were eight rows wide (four beds). Row length was 816 feet at King City and 600 feet at Spreckels.

The Blackwelder spray blocker was used when the beet seedlings were at the 2-leaf stage. The Milton finger weeder was used at the same time; then a week later the Milton weeder blocker, which left 1½ inch blocks on approximately 4 inch centers, was used on the treatment. The hand thinned treatments were thinned at normal thinning time.

Stand counts were made after thinning in which the single, double and multiple blocks were tabulated.

The trials were harvested with a 2-row Marbeet harvester and 25 samples were taken from each treatment to check the percent sugar and percent tare.

[1] Respectively: Assistant Agricultural Superintendent, Assistant Field Superintendent and Agricultural Engineer, Spreckels Sugar Company.

Results of the trials are here tabulated:

Table 1.—King City.

Treatments	Tons per Acre		%	Beet Containing Blocks	Single Containing Blocks
	Gross Sugar	Beets	Sucrose	per 100 ft.	per 100 ft.
Hand thinned	3.698	23.46	15.78	147.0	96.5
Milton blocker	3.320	21.12	15.76	154.4	50.2
Blackwelder spray blocker	3.314	20.94	15.82	98.0	56.2
Sig. dif. 19:1	0.185	0.99	N.S.	23.9	5.7

Table 2.—Spreckels.

Treatments	Tons per Acre		%	Beet Containing Blocks	Single Containing Blocks
	Gross Sugar	Beets	Sucrose	per 100 ft.	per 100 ft.
Hand thinned	2.888	20.68	13.96	138.4	97.3
Milton blocker	2.798	19.68	14.22	151.1	46.1
Blackwelder spray blocker	2.272	16.26	13.98	110.0	57.5
Sig dif. 19:1	0.253	1.63	N.S.	9.98	3.2

Strip Trials in Commercial Fields

Seven strip trials located in the Salinas valley area were used in this study.

The Milton blocker and the Eversman blocker were used with a variety of different tool attachments.

The plots in each field consisted of: Two beds or four rows thinned by one of the above mentioned mechanical thinners and two beds or four rows adjacent to them thinned by hand.

At harvest time in six of the trials, portions of these strips were harvested by hand. Five 50-foot blocks were measured at random throughout the field making a total of 1,000 feet of row from each treatment harvested. All the beets were topped and placed on the beds. The non-marketable beets (less than 1 inch in diameter) were picked out and counted, then discarded. The remaining marketable beets were then counted and weighed. Two samples consisting of ten beets each were taken from each replication for sugar and tare deteriorations.

The remaining strip trial was harvested by a Marbeet harvester. The entire length of the strips was harvested, and ten samples from each treatment were taken for sugar and tare determinations. Results of these strip trials follow in tabular form:

Table 3.—Hand Harvested Strip Trial.

Treatments	Tons per Acre		%	Total Beets per 100'	Marketable Beets per	[1]Value of Beets per
	Beets	Sugar	Sucrose	Row	100' Row	Acre
Hand thinned	26.48	4.23	15.9	120.1	114.4	$296.18
Machine thinned	23.78	3.87	16.2	142.8	124.1	271.04

[1] Based upon the net selling price of sugar at $5.85 plus government payments.

Table 4.—Machine Harvested Strip Trial.

Treatments	Tons per Acre		%	Average %	[1]Value of Beets per
	Beets	Sugar	Sucrose	Clean Beets	Acre
Hand	30.13	4.72	15.6	95.5	$329.75
Milton	26.03	4.41	16.9	92.8	309.53
Milton plus hand trimming	25.64	4.24	16.5	92.5	297.15

[1] Based upon the net selling price of sugar at $5.85 plus government payments.

In localities such as the Salinas valley thinning and hoeing costs are exceptionally high. Under these conditions, a loss of $25.00 in the value of beets per acre (as shown in Table 3) could well be offset by savings in labor.

Summary

Some of the pertinent points which were learned during the past year are as follows:

1. Beds should be rolled before using a mechanical thinning device. The more uniform the bed, the more accurately the machine will work.

2. Beet stands planted with precision planters are desirable to insure good results with stand reducers.

3. Any use of spring mechanization tools will tend to increase the length of skips in the beet row.

4. Stands which have more than 1,000 plants per 100 feet of row are difficult to thin mechanically. These can be reduced by going over them several times with a mechanical finger weeder, but the thinned stands are not uniform, and contain many multiple beets.

5. Seedling stands which range from 400 to 800 beets per 100 feet of row offer maximum possibilities in reducing costs of hand labor.

6. The Eversman weeder-blocker operates moderately well if the soil is friable. The tool is power take-off driven so the weeder head may travel faster than the ground speed. The weeder attachment works best in uniform heavy stand of small seedlings.

7. The Milton weeder-blocker does its best work when the soil is friable, the beds are smooth and when the beets are in about the 4-leaf stage. It is convenient to set up, and is adjustable over a wide range of block-widths and centers, but requires considerable judgment to obtain best results.

8. The Blackwelder spray blocker tends to leave the greatest number of single plants and has the important advantage of not disturbing the soil. It should be used when the seedlings are in about the 2-leaf stage. The uniformity of the bed is not important because it is free to move up and down with the irregularities in the rows. The machine is still experimental, but holds much promise.

9. Fourteen to twenty-one days following the mechanical thinning, good results were obtained by using short handled 4-inch hoes in order to clean out some of the larger clumps of multiple beets, and at the same time hoe out the weeds. In some cases this one hoeing was sufficient for the season.

10. It was necessary to use small blocks in order to compete with the heavier stands which are customary in the Salinas valley. The average post thinning stand for the 1949 season was 125 percent.

11. Better results were obtained from mechanical thinning on soils of high fertility. Poorer soils cannot support the high population of mechanically thinned beets.

12. A mechanical harvest is necessary if beets are mechanically thinned. Hand crews will not pick up the small beets, whereas the machine harvester will.

13. A satisfactory and profitable crop can be grown by using a mechanical thinning device.

Union Sugar Company's Random Stand Reduction to Pre-determined Row Population

CLARENCE NIELSEN[1]

California will probably harvest 80 to 85% of its sugar beet crop with machines in 1949. A 100% mechanical harvest with a higher yield in tons of beets and sugar than any hand harvest or combination of hand and machines and at less cost is possible. It could be an accomplished fact except for the vagaries of a small element of the human factor involved. The transition from a hand to a mechanical harvest has occurred over a period of about six years. Wartime labor shortages and productivity made this a dire necessity. The alternative was a serious detraction from the war effort and a huge financial loss.

Mechanization of the spring work has not been faced with the critical urgency which was the motivating factor in the harvesting of the sugar beet crop. The type of effort necessary to thin, hoe and weed was recruited among a labor force which was incapable of the hard physical labor that hand harvesting demands. A limited and often insufficient supply of hand labor has since been available. Segmented seed, light rates of seeding and partial mechanization have been stop gap practices toward spring mechanization. A field which could not be cared for properly could be worked over and replanted or planted to another crop without too serious a financial loss. A consistently good return from sugar beets afforded a cushion for a small increase in cost. As a consequence full mechanization of the spring work will probably not be with us as early as it would if the spur of necessity were applied as it was with the harvest.

The experience and facts recorded here have been gained and assembled in the coastal valleys and the Imperial valley of California. Much of it would apply to the great inland valleys, the Sacramento and the San Joaquin, but there are some differences such as method of planting and type and supply of field labor. In the coastal and Imperial valleys the planting is practically all ridge or bed planting. Two rows twelve to fourteen inches apart are planted on beds ridged up to thirty-eight to forty-two inch centers, leaving the rows of beets from twenty-six to thirty inches apart across a furrow from four to ten inches deep. This method of planting precludes any across the row blocking, thinning or weeding operations with any of the present mechanical equipment. We are confined to down the row operations. Some good equipment for down the row blocking, thinning and weeding has appeared from many different sources and there has been some adaptation of equipment not specially designed for that purpose. Some of it is designed to do a part of the job followed by hand work and some equipment designed for follow-up operations. One type of equipment is

[1] Superintendent, Northern Division.

intended to do a finished job, including subsequent hoeing. None of it has been accepted readily by the growers at this writing. The average grower still has in his mind a thinned stand of single plants eight, nine or ten inches apart as the case may be, with all the weeds removed, as a thinning job well done.

In trying to accomplish this end much experimental blocking has been done, that is, cutting out a section of row and leaving a section on certain centers. After five or six years of experiments there is still not a single grower who has adopted it as a regular practice. Many outstanding demonstrations have been made of the possibilities of blocking. Most notable was a field in which grower stated he wanted one hundred twenty beets per 100 feet of row. Several beds were blocked which showed an average of 135 beet-containing blocks per 100 feet of which 87 were singles. But it did not satisfy the grower. There are several reasons for this. Too often in blocking the tool seems to remove the largest and thriftiest plant with the weak one remaining and also removes the single beet which would fill a gap if left standing. Secondly, our plantings are in the winter and early spring with weeds a major factor. The cost of cleaning out the weeds and removing the multiples almost equals the cost of hand thinning. When the option of selection is taken away from the laborer by predetermined spacing efficiency seems to fall off tremendously.

During the thinning season of 1949 we attacked spring mechanization from the angle of stand reduction with equipment designed to obtain the same results as the bean or pencil weeder used across the row; also by blocking to extremely small blocks such as 1" cut 1" block. Milton, Eversman, Winpower and Dixie equipment was used. The Dixie beet thinner seemed best adapted to experimentation because different cutters could be built and bolted on the working head and variable speeds could be obtained by changing sprocket ratio between the driving wheels and the working head. A plate was made to bolt on the working head of the Dixie which embodied eight small cutting knives designed to make from a 1" to 1½" cut. A weeding head of side delivery rake teeth was built holding twelve teeth evenly spaced. Another was built consisting of four pairs of double rake teeth quartering on the circle. The latter proved impractical on account of difficult timing and its hopping and jerking performance.

It has been proven and is generally conceded that equal production of both tonnage and sucrose can be obtained from harvested stands of beets which exceed the conventional 100, 120 or 130, etc., per 100 feet of row. Stands in excess of this within reasonable bounds produce equal tons per acre and tend to produce more sucrose per acre. Our local University Extension Service has developed a rule over a period of years which sums up as follows:

> A soil type which will normally produce fifteen tons per acre will mature to marketable size (marketable size being considered beets larger than 1¼ inch diameter) one hundred fifty beets per 100′ of row in twenty-inch rows. Progressing further, a soil which can be expected to produce twenty tons per acre will mature about 200 marketable beets per 100′ of row and soils more fertile

will stand a slight increase above 200 beets per 100′ of row. Any particular increase above these points does not produce any more marketable beets and if increased materially quickly results in less marketable beets. To further evaluate the above theory our farm advisor conducted population experiments in fifteen grower's fields in 1949. Two records were lost. The summary is the result of thirteen trials under regular field conditions using the grower's whole field and crop as a check. Trial records are based on a 100′ length of row harvested by hand three different places in the plot. In harvesting the trial plots, beets 1¼″ in diameter and less were discarded. Stand reduction was by machine, using various cuts and blocks as the situation seemed to justify to obtain an average of the aforementioned populations. Population per 100′ after machine stand reduction varied from 160 to 422. Hand thinning check fields varied from 100 to 150.

A detailed tabulation is given in Table 1. The average result was as follows:

Beet Per 100′ Row	Beets Harv. 100′ Row		Yield Tons Per Acre		Sugar Cont. Percent		Sugar Per Acre	
Mach. Thin.	Mach. Thin.	Hand Thin.	Mach. Thin.	Hand Thin.	Mach. Thin.	Hand Thin.	Mach. Thin.	Hand Thin.
251	191	123	21.9	22.3	17.2	17.2	7,612	7,735

Of the thirteen trials two showed no significant difference. Five showed results in favor of machine thinning. Six showed results in favor of hand thinning. The difference in number of beets after thinning and beets harvested represents beets 1¼″ in diameter or less. These were discarded and not computed in total weights and averaged approximately 400 pounds per acre, tops included.

We conducted an experiment along the above lines thru the center of a fifty-five acre field. It comprised twelve beds 1,835 feet long. Four beds were planted by a John Deere No. 66 planter 11.6 cells per foot. Four were planted with the same planter 4.5 cells per foot and four were planted with a Planet Jr. unit attempting to plant ten pounds per acre. Very fine emergence was obtained from the John Deere planting but the Planet Jr. planting was too deep and emergence was very irregular. Only the very strong thrifty seedlings emerged together with some groups of seedlings which happened to be in a partially closed portion of the seed furrow or otherwise shallow spot of planting. It was a freak stand altho it appeared to be normal on a 100″ count. The field was judged capable of producing twenty-five tons per acre and we were attempting to leave from 250 to 300 beets per 100′ of row. This grower was high-population minded and his thinning averaged 158 beets per 100′ of row and the yield for the whole field averaged 27.68 tons per acre, 18.1 sugar. The trials yielded less than the check. The difference in tons per acre was 1.31 for J. D. 11.6 cells per ft.; 2.05 for 4.5 cells per ft. and 4.14 tons less for the Planet Jr. planting. The average was 2.5 tons per acre less than the grower's field. All of the

Table 1.—Results of Machine Thinned Versus Hand Thinned Sugar Beets, 1949 Season[1]

	1	2	3	4	5	6	7	8	9	10	11
	Beets 100 ft. Row After Machine Thinning	Beets Harvested 100 ft. Row		Yield Tons per Acre		Percent Sugar		Sugar per Acre		Plus or Minus Yield Compared to Hand Thinned	Comments
		Machine Thinned	Hand Thinned	Machine Thinned	Hand Thinned	Machine Thinned	Hand Thinned	Machine Thinned	Hand Thinned		
1	185	150	97	21.45	21.82	20.6	20.4	8,837	8,902	Same	
2	231	175	129	15.47	14.95	19.6	20.0	6,033	5,980	+	Nematode
3	230	146	108	8.58	9.42	20.1	19.83	3,603	3,738	Same	Nematode
4	308	214	132	18.85	23.33	16.53	15.83	6,215	7,386	—	Soil compacted by machine
5	368	308	124	28.8	28.8	18.00	17.3	10,576	10,165	+	
6	160	151	126	24.0	25.8	16.37	17.1	7,853	8,825	—	Poor stands
7	170	129	126	17.94	19.4	17.1	17.83	6,135	6,860	—	
8	235	196	120	32.51	30.0	17.9	17.66	11,642	10,596	+	Check—field ave. Test double fert'd.
9	272	202	118	15.19	16.71	14.96	15.2	4,622	5,079	—	Sand; lack of moisture
10	214	178	114	26.78	23.40	15.2	14.65	8,141	6,856	+	
11	422	247	140	23.58	25.81	15.6	15.59	8,772	9,596	—	Check—field ave.
12	225	201	146	29.51	26.78	16.3	16.6	9,620	8,890	+	
13				22.6	24.5	15.3	15.7	6,915	7,693	—	
Average	251	191	123	21.9	22.3	17.2	17.2	7,612	7,735	2 —	no significant diff.
										5 —	favor of machine thinn.
										6 —	favor of hand thinning

[1] The difference between the number of beets after thinning (column 1) and beets harvested (column 2) represents beets not harvestable under 1½ inches in diameter. These were discarded and not computed in total weights. The total weight per acre of such beets averaged approximately 400 lbs. per acre.

Table 2.—Result of Machine Thinned Versus Hand Thinned Sugar Beets, 1949 Season.

[1]Pre-Thinning Stand Per 100″ Rule					[2] Harvest Count per 100′					Yield per Acre Clean Weight		
Total Beets	Beet Inches	Singles	Doubles	Multiples	Total Beets	Marketable Beets	Singles	Doubles	Within Multiples	Tons	% Sugar	Pounds Sugar
John Deere No. 66 Planting 11.6 Cells per Foot												
67.6	37.6	20.5	9.1	8.0	418.5	197.6	53.6	53.6	90.3	26.37	18.3	9,651
John Deere No. 66 4.5 Cells per Foot												
26.4	16.0	8.6	5.2	2.2	237.5	121.6	60.0	29.3	32.3	25.63	18.2	9,329
Planet Jr. Planting—10 lb. per Acre												
38.4	25.4	17.2	5.8	2.4	239.6	98.5	22.5	22.2	53.8	23.54	18.9	8,898
Total and Averages												
132.4	79.0	46.3	20.1	12.6	895.6	417.7	136.1	105.1	176.4	75.54	55.4	27,878
44.13	26.33	15.43	6.7	4.2	298.53	139.2	45.4	35.0	58.8	25.18	18.46	9,293
						Grower 55 Ac. Field Check Hand Thinned				27.68	18.1	10,020
						Difference Favor Hand Thinning				2.50		727
						Value Difference at $6.50 Net				$29.02		
						Grower Thinning Cost				34.21	Trial	8.24
						Grower First Hoeing				19.89	Trial	7.06
						Totals				54.10		15.30
						Difference in Cost in Favor of Trial					38.80	

[1] All counts are an average of six. [2] Harvest count not by conventional 100″ method. A *single* was a marketable beet standing alone; *Doubles*, only two in a group; *Among Multiples*, a marketable beet or beets among groups of three or more non-marketable beets. [3] It should be noted that although the grower's field exceeded the mechanically thinned trial plot by 2.50 tons per acre, the grower's cost for thinning and weeding exceeded the trial by $38.80 per acre, which was more than the value of the increased production.

beets were harvested by the grower with a Marbeet harvester and were handled, hauled, sampled and tared in the same manner.

A detailed tabulation is given in Table 2. Average results follow:

Yield Per Acre									
Total Beets		Marketable Beets + 1¼" Dia.		Tons Clean Wt.		Percent Sugar		Pounds Sugar	
Trial	Check	Trial	Check	Trial	Check	Trial	Check	Trial	Check
298.5	158	139.2	148	25.18	27.68	18.5	18.1	9,293	10,020

In studying the detailed statistics it was noted that the Planet Jr. planting showed a much higher proportion of marketable beets among multiple groups. These were necessarily smaller beets than singles or doubles. This planting could not be reduced too severely without getting too low a population. The difference in yield in our judgment was due to poor distribution. If the Planet Jr. record were eliminated the other plantings would average 1.68 tons less than the grower's field. There was a remarkable difference in the weed crop between the hand and machine-thinned in favor of the machine-thinned at the first hoeing. No counts were made but it was judged that there were only ten percent as many weeds at first hoeing in machine-thinned beets as compared with hand-thinned.

In summarizing we realize that we did not have sufficient replications to establish any fixed conclusions but we believe we are pioneering a field which merits further study. This principle may find better acceptance by growers because it attacks both thinning and weeding mechanically.

We believe we have learned that a sugar beet crop can be produced by mechanical thinning only which will compare in net returns to a hand-thinned crop. We believe that the stand reduction principle and the use of small cuts and small blocks is superior to wide cuts and blocking, but a good full stand well distributed in the row is essential in obtaining a successful result. The better the stand to start with the more severe the work on the row may be. The more work on the row to reduce to a predetermined population the better the distribution of beets left for harvest and the fewer the weeds.

A Year's Experience Using an Electric Eye Thinner

LESTER J. HOLMES[1]

Before discussing the latest development in mechanical thinning, I believe that a short review of the sugar beet culture as I first became acquainted with it in 1921 might be advisable. Being a comparatively new industry in our territory, complete reliance on the fieldman for all procedure was necessary. Seed and labor were relatively cheap, and horses an important factor for motive power, especially for planting and cultivating. Seed bed preparation was relatively unimportant as a heavy seeding rate, 20-25 lbs. per acre, was used in order to obtain a thick and continuous stand. Next, this thick stand must be thinned to single beets twelve inches apart, with great emphasis placed on singles, as well as 100 beets per 100′ of row. After the men proceeded to thin to singles the field appeared to be destroyed; however, the next day all remaining beets were standing up again.

During this period of approximately thirty years, it was being brought more and more forcibly to the industry that this was wasteful, not only in seed, but also in manpower, and determined efforts were made by sugar processors, manufacturers, agricultural colleges and progressive farmers to mechanize the production of sugar beets.

We are all familiar with the progress made in planters, cultivators, harvesters, as well as many devices to reduce the beet populations, including also the development and use of sheared and decorticated seed.

Spring mechanization progressed slowly as the main difficulty was the elimination of the single plant idea, as well as absolute uniform spacing. Great progress has been made in this field of study and today a few doubles are not considered detrimental to yield, consequently many types of blockers and thinners are available. However, blockers and thinners, whether of the pendulum or rotating type, have no plant selection ability, therefore skips are widened, and healthy plants destroyed with the weak.

In attempting to overcome this weakness, Mr. Leo Marihart of Salinas, California, hit upon the idea of electronics, using the so-called electric eye. In connection with Hewlitt Packard Company, outstanding electronic engineers of Palo Alto, California, they developed such a machine which has been successfully operated over several years. Like all new developments this machine started as a clumsy, crude affair, but has now developed into a compact, clean unit, capable of being mounted on practically any wheel tractor.

The machine is composed of three units, namely the control box, the electric eye, and the knives. They are mounted on a tractor, and can work, day or night, any desired number of rows, or row spacing, as the machine works down the row. Four rows thinned at one time has proved to be the most efficient operation of this equipment.

[1] Manager, American Crystal Sugar Company, Clarksburg, California.

I am indebted to Mr. Marihart for the following description of the thinner:

> "Basically, the machine consists of a photo-tube, or, as it is more commonly known, an electric eye, with its own light source and of a definite color range. The eye and light source are so mounted that they are carried at any desired setting along the row of plants. Due to the wiping action of the unit, whereby the foliage of the plant is literally pushed forward, the eye actually sees the foliage, or leaves, near the roots, and by this means determines the root location."

The impulse picked up or received by the electric eye is amplified greatly and made to operate the timer. The timer is controlled both mechanically and electrically, which means any variation of tractor speed does not affect the timing of the machine. Several adjustable switches are so placed that any desired thinning distance may be obtained at any fractional setting, and this range, for all practical purposes, is from six inches to sixteen inches. Other adjustments are possible with minor changes.

The timer in turn controls the action of the knives. At present, there is mounted a one-hundred-twenty degree clutch action with two sets of knives for each one-third revolution. These knives are spring-mounted so as to simulate hand hoeing. To explain, rather than having knives which are rigidly mounted on a rotatable shaft, whereby this action is one of radially cutting through the ground, limited by the radii of the cutting edges and the shaft, the spring-mounted knives are offset, allowing a six- or seven-inch cut through the ground at a predetermined depth set by the grower. Furthermore, the loosened earth is left, providing a mulch around the plant. The knives are so mounted to allow one knife to cut in front of the plant and the other knife in back of the plant. Necessarily, the knives are laterally adjustable to allow any desired plant clearance; in other words, this clearance would not be the same for plants in the cotyledon stage and a plant having nine or ten leaves. It should be understood only one setting, ordinarily, is necessary for any field in any desired condition of growth to the limits already mentioned, viz., plants so large so that the down the row growth is solid. Minimum tearing of the leaves of the larger plants is avoided by the undercutting action and design of the knives.

Although there may be skips in stands throughout the fields, due to the overlapping of the knives in their cutting action, the area is usually cleaned. For example, if a crop is being thinned and the spacing is twelve inches, ten-inch knives may be used, then when the next cut is made the other plant could be twenty inches away and the knives would clean the whole area.

As previously stated, the photo-tube and light source are so mounted that they travel down the plant row guided by the tractor driver. The tractor driver can control the sensitivity of the photo-tube by a dial similar to one on a radio. This sensitivity can be set to respond to a small or a large plant. Once this setting is made it can be left alone and the photo-tube will respond

accordingly. However, if the plants at the end of a long row are smaller the sensitivity can be changed to accommodate them. This can be done at any time, even while the machine is operating. It is similar to tuning a radio. Wherever the best response the dial is set, and any change in reception can be adjusted accordingly.

Assuming the driver has made his setting and starts his tractor down the row of plants, the machine functions as follows: The photo-tube receives an impulse from a desired plant; immediately this is amplified and the photo-tube is made inoperative. The setting the operator or driver had made for

Figure 1. The Marihart electric eye thinning machine in use near Clarksburg, Calif.

his thinning distance determines when it will again be operative, as previously explained, as the impulse is carried on through to the time the photo-tube as stated is again made operative, and the clutch actuated allowing the knives to cut out all but the desired plant, located by the photo-tube, and at the desired distance.

This machine will thin plants any desired spacing. This variation in spacing is controlled electrically, and when a desired setting is made by turning a dial, let us say at 8, 8½, 9, 9½, etc., this spacing is kept accurately

for the entire field, so much so that it can be checked by measuring any of the various plants with a tape. By this means uniform desired distances between plants can be obtained, or, to state it another way, due to various growing conditions, i.e., conditions of the soil, moisture factors, fertility, etc., it is possible simply by setting a marked dial to secure the desired population of plants which the grower deems suitable so that his field can produce the maximum tonnage or yield.

Another advantage is the ability of the selection of plant size. Very often, due to field conditions and weather, plants do not germinate uniformly, causing many variations in plant size about thinning time. By means of two settings on the machine, a grower is able to select the larger plants and thus insure himself of more uniform growth.

Following thinning and before the plants grow into a solid row, a grower may weed as often as he thinks necessary.

While we had heard indirectly about the machine no particular attention was paid to it until the third experimental machine was made. This machine worked in the Salinas valley thinning and hoeing about 1,000 acres of broccoli, lettuce and sugar beets and also was taken to Imperial valley.

As our sons have taken over active farming operations, several trips were made in the company of other growers to observe the machine in action. We became convinced that the machine would do a satisfactory job, if properly operated.

Having decided that the machine was practical, although slightly premature, as it was ahead of development of planter, seed emergence, etc., a four-row unit was purchased to be mounted on an International Model H by Mr. Marihart. As all previous work had been done with John Deere tractors this required more time than anticipated, so the machine arrived in midseason. There were the usual disappointments and delays that follow any new ideas, but with wholehearted cooperation from all parties concerned the faults were gradually eliminated.

This required considerable patience and perseverance, not only with the boys, but also with the manufacturers. One boy took over the operation of the entire ranch, while the other spent his entire time with the machine during the day, then in company with engineers worked on it at night, until it was finally redeveloped to suit our soil and planting conditions. Fig. 1 shows the machine in the field, and Fig. 2 is a close-up of the mechanism.

During the course of operations 160 acres of beets were thinned satisfactorily. After thinning, a crew was sent there with instructions to clean out bunches left, and do no hand work at all. As the average single count was about 55% no attention was paid to doubles or triples. The cost of this work was very little and really consisted of a light hoeing job.

On account of the late start and the rapid growth, they were unable to go over very much of the acreage the second time, but did enough to convince all concerned that it was not only possible but practical.

In both fields check plots were left, and thinned and hoed in the usual manner. Differences in tonnage and sugar content were not significant.

In the first field the machine-thinned field was slightly better in tonnage, with no difference in sugar content. In the second field the hand-topped seemed to be slightly better in tonnage, with no difference in sugar content.

Figure 2. The Marihart thinner in detail. The light source and photo cell (right foreground) record on the timer (not shown) the electrical impulse which rotates the thinning knives by engaging a clutch (left foreground).

All beets were harvested mechanically and the results were observed by the distance traveled to obtain a load. Both fields yielded approximately 18.5 tons to the acre with 18.99 and 19.59 sugar.

As the machine will cover from an acre to an acre and a half per hour, you can see that there is a great saving over the conventional hand method of thinning.

Our observations of the machine are as follows:

First, the machine is practical. This perhaps could be qualified by saying that you must have an operator who will take some interest in the performance of the machine.

Second, you must farm with the mechanical thinner in mind. This is important. Due to weather conditions the seed bed was not prepared

properly, yet the machine did an acceptable job under cloddy conditions. The stand of beets should be fair, but need not be as heavy as desired for cross-cultivation or hand thinning.

Third, you can start thinning a little earlier than otherwise, and by working both day and night eliminate all the stoop work from the sugar beet crop.

We also believe that one of the important points is that the beets are not disturbed, and will continue their growth, which certainly is not possible under hand thinning methods, at least in our territory. The present machine is so designed that replacement parts can be installed by the tractor driver. Spare units are available and can be substituted immediately.

The boys, like myself, have a special aversion to handling a hoe, but what modern youth, boy or girl, will not sit on a tractor in the shade of an umbrella, and blithely watch the weeds and extra beets disappear beneath him. Certainly, electronic machines of this type will become commonplace in a very short time on our progressive farms, and the man with the hoe will play only a minor part in the sugar beet industry in the U.S.A.

General Agronomy

Plant Population Experiments with Sugar Beets at Fort Collins, Colorado[1,2]

G. W. DEMING[3]

The relation of sugar beet stand, or plant population, to acre yield of sugar beet roots and sugar has been studied in the period 1937-1949 in the agronomic experimental work of the writer at Fort Collins, Colorado. This paper reviews briefly the older experiments which have been previously reported in some detail and gives additional information from the experiments of 1948 and 1949.

The experiments have been conducted on Fort Collins Clay Loam soils of the agronomy farm at the Colorado A & M College Agricultural Experiment Station. The sugar beet seed used has been the standard commercial variety currently issued to growers of the Fort Collins district by the Great Western Sugar Company. With the exception of experiments involving different row widths as a variable, the standard row width used was 20 inches. Various plant populations have been attained by differential basic spacings of hills in the row and by varying the proportions of skips, 1-, 2-, and multiple-plant hills in the stands. Distribution of the different types of hills in a stand has been at random, usually as determined by drawing random numbers. In general the attained stands have approximated very closely the stands as planned. All the experiments have been of randomized block or Latin square design with a minimum of 5 replications.

The 1937-39 series of experiments compared spacings of single plants at 8, 12 and 16 inches with 100, 70 and 40 percent stands of each spacing. The conclusions reached were: (1) With approximately equal yields from full stands of all three spacings the 12-inch spacing appeared to be the optimum. (2) As stands were reduced yields declined, but the declines in yield were not proportional to the reductions in stand. In general a 70 percent stand could be expected to produce about nine-tenths as much as a full stand, a 50 percent stand three-fourths and a 30 to 40 percent stand two-thirds of a normal crop. (3) Percentage sucrose declined as stands were reduced, but marked reductions in quality of the roots did not occur until stands dropped below about 60 plants per 100 feet of row (1, 2, 3, 5).[4]

In 1941-43 beets planted in the first half of April with 100, 70, 50, and 30 percent stands of single plant hills were compared with a full stand of beets planted in mid-May. The conclusions were: (1) That it would usually be more profitable for a grower to save as little as a half stand of timely planted

[1] Agronomic investigations of the Division of Sugar Plant Investigations at Fort Collins, Colo., are cooperative with the Agronomy Section of the Colorado A & M Agricultural Experiment Station and are conducted on its Agronomy farm.

[2] Scientific Journal Series No. 325. Colorado A & M College Agricultural Experiment Station.

[3] Agronomist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

[4] Numbers in parentheses refer to literature cited.

beets than to replant in May. (2) The conclusions reached from the 1937-39 tests as to the proportion of a full crop which could be expected from 70, 50 and 30 percent stands and the poorer quality of beets from reduced stands were confirmed (1, 2, 3).

A study of yields from thin stands in rate of planting tests in 1944-45 and a plant population experiment in 1945 in which full and reduced stands in which 25 percent of the plant-containing hills (15, 25 and 35 percent in the case of the 70 percent stands) had two or more plants per hill were compared with a full stand of single plant hills led to the conclusion that the hill was the unit of stand which determined sugar beet yields (4). This conclusion was the basis for the following recommendation:

> "The thinned stand of sugar beets, by whatever method it is obtained, should consist of as high a proportion of single-plant hills as can be obtained from the initial stand of seedlings without reducing the total stand of well distributed hills below the maximum number obtainable up to a full stand."

In 1946 full and reduced (70, 50 and 30 percent) stands of single-plant hills were compared with similar stands in which 25 percent of the plant-containing hills were 2-plant and multiple-plant hills. This experiment confirmed the conclusion that the hill, irrespective of the number of plants it contained, was the unit of stand which determined sugar beet yields (5). Consideration of the relation of this concept to machine thinning of sugar beets led to the following conclusions and recommendations:

> "In machine thinning of the sugar beet crop the aim should be to leave as full a stand of hills as is obtainable from the initial stand being worked. Few roots of marketable size are likely to be produced in hills containing more than a maximum of 3 plants. Therefore, precision planting of high quality sheared seed on a clean and well prepared seedbed must be the foundation for the thin, uniform initial stand from which an approximately full stand of predominantly 1- and 2-plant hills can be saved by the appropriate machine operation."

Since the conventional 20-inch beet row seems somewhat narrow for the best operation of large-tired tractors and some beet harvesters an experiment was conducted in 1947 to determine the effect of width of row on yields of sugar beet roots and sugar. Row widths of 22, 24, and 30 inches and alternate rows of 20- and 40-inch widths were compared with the standard 20-inch row. Total plant populations were varied by holding the row spacing of single plant hills constant at 12 inches for all row widths. In other treatments populations were held at approximately 26,000 plants per acre, the normal stand at 20x12-inch spacing, by varying the spacing in the row or the inclusion of a portion of 2- and multiple-plant hills according to the row widths. In general, yields declined as row widths increased. Increasing the number of plants in the row had little effect on yields; row width was the determining factor (6). The conclusion was that since reductions in yield were relatively small in the case of small increases in row width, the greater convenience of operating machinery might justify the use of 22-inch, or possibly 24-inch, rows.

Plant Population Experiment, 1948-49

It is obvious that some of the sugar beet plants in multiple-plant hills

will not produce roots of sufficient size to be saved at harvest. It would seem that this condition would result in somewhat lower recorded yields from stands in which part of the hills contained two or more plants than from comparable stands of single-plant hills. In the experiments conducted from 1944 to 1947 the differences in yields from such stands were usually small and could not with certainty be considered significantly different. However, the small differences observed in yields of roots were often in favor of the single-plant stands. Sometimes a slightly higher percentage sucrose in the roots from the stands containing multiple-plant hills compensated for the slightly

TABLE I. Detail of treatments included in sugar beet populations experiment, Fort Collins, Colo., 1948-49.

Treatment No.	Basic spacing	Hills per 100 feet of row				Total plants per 100' row
		Blank	1-plant	2-plant	3-plant	
	(inches)					
1.	12x20	0	100	0	0	100
2.	8x20	0	150	0	0	150
3.	8x20	50	60	30	10	150
4.	12x20	0	70	25	5	135
5.	12x20	20	56	20	4	108
6.	12x20	30	49	18	3	94
7.	12x20	40	42	15	3	81
8.	12x20	50	35	13	2	67

smaller yield of roots and calculated yields of gross sugar were almost identical. To obtain additional evidence on this point an experiment was conducted in 1948 and repeated in 1949. The treatments included in this experiment are given in table 1. The test was planted as a Latin square. The plots were 8 rows 6 feet in length, of which the four inside rows were harvested. Distribution of the various types of hills was determined by drawing numbers for each plot. In 1948 the attained thinned stands were with a few exceptions in fair agreement with the planned stands and in 1949 all stands were in excellent agreement. Planting was timely in both years but in both years thinning was slightly late because of weather conditions. Acre yields of gross sugar and roots and percentage sucrose for both experiments are summarized in table 2. In the second portion of this table the data are experessed as percentages of the check (treatment 1).

In these experiments none of the treatments equalled the check in yields. However, the yields of the full stand of single-plant hills spaced 8x20 inches was, as usual, only slightly, and not significantly, lower than the check.

The evidence from these experiments as to percentage sucrose in the beets from the different treatments is in reasonable agreement with the evidence from earlier experiments. The conclusion is that under the conditions at Fort Collins there is no marked decline in quality of the roots produced in reduced stands until the stands fall below about 70 hills per 100 feet of row.

In general the harvest crew did not save beets which were less than about 1 inch in diameter at the crown. Such beets were rare in the check

plots, but were found in appreciable numbers in the other treatments; particularly treatments 2, 3 and 4. Treatment 4 with a full stand of hills, 30 percent of which had one or two additional plants, produced appreciably lower yields than the check; the differences being significant in 1949 and for the average of the two experiments. The reduction of approximately 7 percent in yield of roots from this treatment seems too large to be attributed entirely to non-harvest of small beets. In this full stand of hills the additional plants may have had an overall adverse competitive effect.

TABLE 2.—Sugar Beet Population experiment Fort Collins, Colo., 1948 and 1949. Acre yields of gross sugar and roots and percentage sucrose. Data given as 8-plot averages and 2-year average of averages.

Treatment No.	1948			1949			2-year average		
	Acre yields		Percentage	Acre yields		Percentage	Acre yields		Percentage
	Gross sug. (pounds)	Roots (tons)	sucrose (percent)	Gross sug. (pounds)	Roots (tons)	sucrose (percent)	Gross sug. (pounds)	Roots (tons)	sucrose (percent)
1.	6,198	19.63	15.67	7,173	20.60	17.41	6,686	20.12	16.54
2.	6,184	19.51	15.71	7,034	20.16	17.46	6,609	19.84	16.58
3.	5,584	17.75	15.74	6,357	18.49	17.20	5,970	18.12	16.47
4.	5,934	18.68	15.88	6,455	18.83	17.13	6,194	18.76	16.50
5.	5,845	18.90	15.46	6,543	19.22	17.02	6,194	19.06	16.24
6.	5,943	18.87	15.76	6,460	18.54	17.43	6,202	18.70	16.60
7.	5,094	16.78	15.18	5,746	17.10	16.80	5,420	16.94	15.99
8.	5,082	16.62	15.27	5,245	15.81	16.53	5,164	16.22	15.90
Dif. for Sig. (19:1)	400	1.17	0.36	502	1.25	0.54	321	0.86	0.32
	Data expressed as percent of the check treatment.								
1.	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2.	99.8	99.4	100.3	98.1	97.9	100.3	98.8	98.6	100.2
3.	90.1	90.4	100.4	88.6	89.8	98.8	89.3	90.1	99.6
4.	95.7	95.2	101.3	90.0	91.4	98.4	92.6	93.2	99.8
5.	94.3	96.3	98.7	91.4	93.3	97.8	92.6	94.7	98.2
6.	95.9	96.1	100.6	90.1	90.0	101.1	92.8	92.9	100.4
7.	82.2	85.5	96.9	80.1	83.0	96.5	81.1	84.2	96.7
8.	82.0	84.7	97.4	73.1	76.7	94.9	77.2	80.6	96.1

Treatment 3, with a basic spacing of 8x20 inches, one-third of the hills blank and 40 percent of the plant-containing hills having one or two additional plants, produced about 90 percent of a full crop. This yield was approximately of the order to be expected from such a reduced stand and there seems to be no reason to believe that the multiple-plant hills had any particularly adverse effect in this treatment. Treatments 5, 6, 7, and 8 were similar to treatment 3 in that they also produced crops that, on the basis of previous tests, can be considered as approximately normal for such reduced stands of hills.

Although the results of these experiments were not entirely conclusive they suggest that additional plants present in multiple-plant hills may have some adverse effect on yields under some conditions. These experiments again confirmed the conclusion that such plants in no way compensate for skips in the stand. Therefore, as machines take the place of hand labor in thinning the sugar beet crop, the aim must be to so plant and thin the crop that there will be a high proportion of single-plant hills in adequate thinned stands. It is unlikely that even the best machine work can ever equal the

nearly perfect stands of single-plant hills that can be attained by the best hand work. However, it is certainly not too much to expect that 70 to 90 percent thinned stands of predominantly single-plant hills can be attained by the proper use of machinery alone. The evidence accumulated in the past thirteen years of experimentation with sugar beet populations at this station indicates clearly that profitable beet crops will be produced from such stands.

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Cultural Experiments with Sugar Beets in Western Nebraska[1]

LIONEL HARRIS, F. V. PUMPHREY AND H. F. RHOADS[2]

Length of growing season is a factor which influences the production of sugar beets in western Nebraska. Short growing seasons have limited sugar beet production on soils of high productivity where the crop has been grown with the best cultural methods. Under these conditions the sugar beet plants have been unable to respond to abundant fertility and good culture because of the limited time for growth. Opportunities for extending the growing season in the fall are rare. However, experience and observation indicate possibilities for taking greater advantage of favorable growing weather in the spring by proper irrigation and planting practices.

Experiments conducted by Nuckols[3] in western Nebraska indicate that early planted sugar beets yield two to four tons per acre more than medium or late planted sugar beets. Better stands were obtained with sugar beets planted March 20 than with sugar beets planted April 30. Frost damage to early planted sugar beets was not as great as the damage to stands caused by insufficient soil moisture for germination at the later planting dates. Nuckols further observed that the time of emergence was more important than planting date.

Time of emergence is determined in many instances by soil moisture conditions immediately after the seed is planted. Sugar beet seed planted early in April sometimes lies in dry soil for several weeks before rainfall is sufficient to insure germination and emergence. Under these conditions the possible advantages of early planting are lost. Because sugar beet seed must be planted shallow, adequate soil moisture for favorable seed germination many times is dependent upon either rainfall or irrigation after the seed is planted. The ridge-cover method of planting has been used in an attempt to conserve the soil moisture available at planting time.

A study was initiated in 1948 at the Scotts Bluff Substation to determine the possibilities of increasing the yields of sugar beets by irrigation for emergence and by the use of the ridge-cover method of planting at different planting dates. The use of the ridge-cover method of planting and of irrigation for emergence have the same objective of providing adequate moisture for germination immediately after the seed is planted. Although other factors such as soil temperature and climatic conditions in general influence the

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[3] Nuckols, S. B. Summary of Date-of-Planting Experiments with Sugar Beets in Nebraska and Wyoming. Proceedings American Society of Sugar Beet Technologists. 185-189. 1946.

germination of sugar beet seed and the emergence of the seedlings, soil moisture is a factor which can be controlled in an irrigated region. The influence of the climate is of sufficient importance to warrant the continuation of this study for several years. The results obtained during 1948 and 1949 are presented in this paper.

EXPERIMENTAL PROCEDURE

The factors studied comprised date of planting, method of planting, and irrigation for emergence at planting time. During 1948 sugar beets were planted April 3 (early), April 18 (medium), and May 2 (late). During 1949 the three planting dates were March 26 (early), April 12 (medium), and May 2 (late). Two methods of planting were used at each planting date: (a) surface or regular planting of sugar beets, and (b) surface planting with a ridge cover. Irrigation for emergence was practiced on one-half of the plots in each planting method at each planting date. The treatments were arranged in a split plot design with six replications of each treatment. The major plot consisted of one individual planting date, the major sub-plot of one method of planting and the sub-plot of one irrigation practice. Each sub-plot of sugar beets consisted of four rows spaced 20 inches apart and 150 feet long.

The study in 1948 and 1949 was conducted on a plot of land which received approximately 15 tons of manure per acre prior to planting time each year. Ridges for the ridge-cover method of planting were made with beet cultivator disks after the seed was planted. The irrigation treatment for emergence was applied one to two days after planting. The ridge cover was removed when the seed started to germinate by dragging one section of a harrow lengthwise of the plot. After the sugar beets were thinned, all plots received the same treatment throughout the remainder of the season. There were five irrigations after thinning in 1948 and six irrigations after thinning in 1949.

EXPERIMENTAL RESULTS

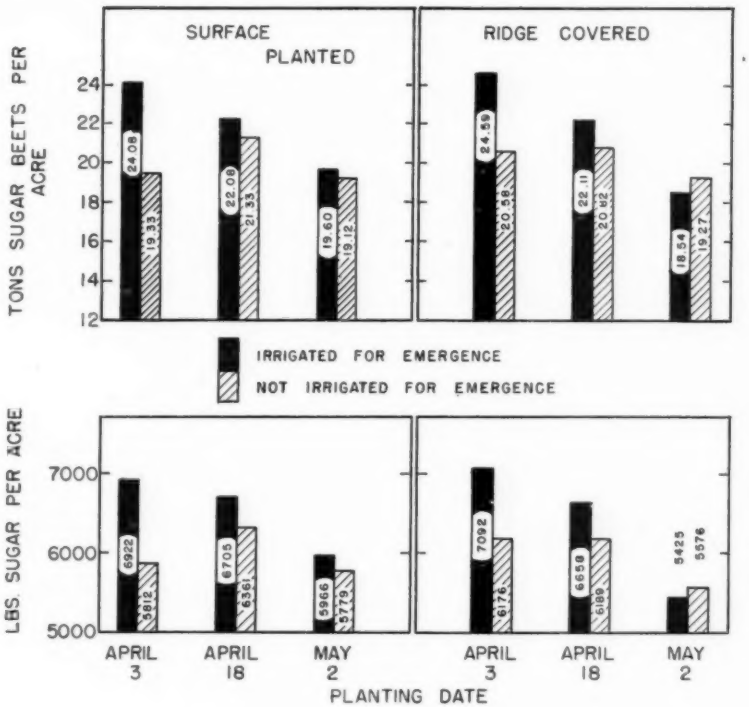
Date of Emergence

In 1948, sugar beets planted April 3 and irrigated at planting time emerged April 19, or approximately two weeks earlier than sugar beets planted the same day but not irrigated. There was approximately five days difference in emergence in favor of irrigation at planting time for sugar beets planted April 18. At the late planting date sugar beets emerged May 14 on both the irrigated and nonirrigated plots.

In 1949, sugar beets planted March 25 and irrigated at planting time emerged April 16, while those planted the same day but not irrigated emerged April 18. During the night of April 15 the temperature dropped to 22° F. and killed many of the sugar beet seedlings from the March 25 planting which were near the surface of the ground. Sugar beets planted April 12 emerged April 25 on the irrigated plots and April 28 on the nonirrigated plots. At the late planting date sugar beets emerged May 12 on both irrigated and nonirrigated plots.

Yields of Sugar Beets and Sugar Production

Influence of Planting Date. A striking decline in the yields of sugar

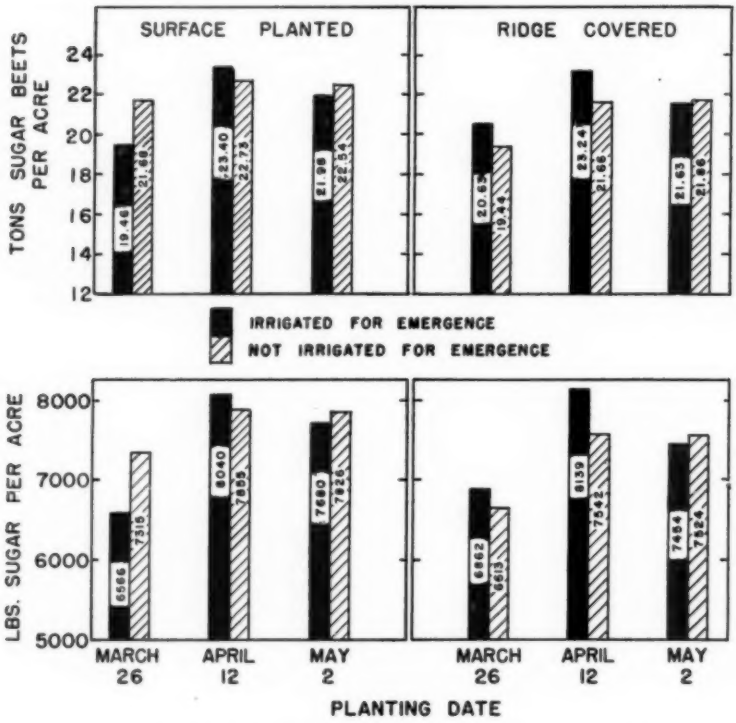


L.S.D. (5% LEVEL) FOR COMPARING:	YIELD T./ACRE	SUGAR LBS./ACRE
TIME OF PLANTING	1.58	348
IRRIGATION FOR EMERGENCE	2.06	545

Figure 1. Influence of planting date, planting method and irrigation for emergence on sugar beet production. 1948.

beets and the production of sugar resulted from delayed planting in 1948 where irrigation was practiced for emergence (Figure 1). This was true with both the surface and ridge-cover methods of planting.

Where irrigation was not practiced for emergence, yields of sugar beets with the ridge-cover method of planting were not significantly different at the three planting dates although the yields of sugar from beets planted April 3 and April 18 were significantly larger than the yields from those planted May 2. However, with the surface method of planting sugar beet yields and sugar production were significantly greater at the medium planting date than at the early and late planting date where the sugar beets were not irrigated for emergence.

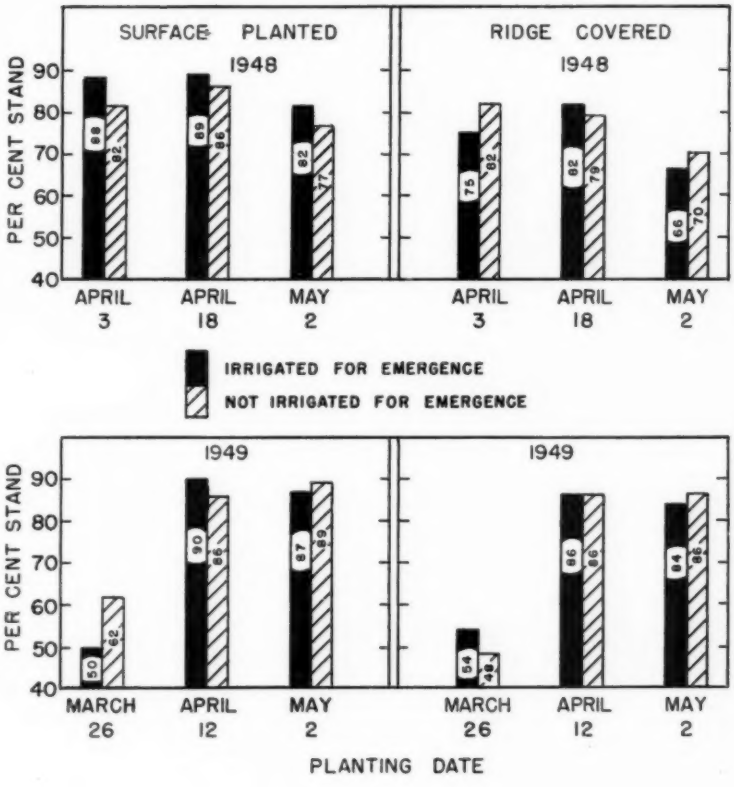


L.S.D. (5% LEVEL) FOR COMPARING:	YIELD T./ACRE	SUGAR LBS./ACRE
TIME OF PLANTING	3.30	787
PLANTING METHOD	1.34	416
IRRIGATION FOR EMERGENCE	1.51	464

Figure 2. Influence of planting date, planting method and irrigation for emergence on sugar beet production, 1949.

In 1949 yields of sugar beets planted March 26 were lower than those planted April 12 or May 2 (Figure 2). This is in marked contrast to the results obtained in 1948 when the highest yields were obtained from early planting (April 3) and irrigation for emergence (Figure 1). In 1948 the early planted sugar beets emerged without damage from frost whereas in 1949 sugar beet seedlings from the March 26 planting emerged at the time of a severe frost and many were killed.

Value of Irrigation for Emergence. Irrigation for emergence at planting time in 1948 resulted in large increases in the yields of sugar beets and



L.S.D. (5% LEVEL) FOR COMPARING:	PER CENT SUGAR 1948	1949
PLANTING DATE	13.9	11.1
PLANTING METHOD	6.8	11.1
IRRIGATION PRACTICE	—	7.5

Figure 3. Influence of planting date, planting method and irrigation for emergence on stands of sugar beets. 1948 and 1949.

sugar at the early planting date, moderate but nonsignificant increases at the medium planting date and small or no increases at the late planting date (Figure 1).

Irrigation for emergence at the early (March 26) planting date in 1949 resulted in a significant decrease in yield of surface planted sugar beets, the

yields being 21.68 tons per acre where no irrigation was practiced and 19.46 tons per acre where irrigation was practiced (Figure 2). Sugar production was influenced in a similar manner. Where the sugar beets were planted with the ridge-cover method of planting there was a small but nonsignificant increase in the yield due to irrigation at planting. These contrasting results due to irrigation for emergence with the two methods of planting may be attributed to differences in stand resulting from variable frost damage under the different treatments.

Irrigation of surface planted beets for emergence produced more rapid and uniform germination than where irrigation was not practiced. Consequently a larger proportion of seedlings on the irrigated plots were near the surface of the ground at the time of the severe frost. This condition appeared to exist also on the ridge-cover planting of March 26, which was not irrigated for emergence. The ridge cover at the early planting date in 1949 appeared to be effective in conserving moisture for seed germination.

There was a moderate increase in yield of sugar beets in favor of irrigation for emergence at the medium planting date in 1949 with both methods of planting although the effect of irrigation was more pronounced with the ridge-cover method than with the surface method of planting (Figure 2). This conforms with the results obtained in 1948 at the medium planting date.

At the late planting date in 1949 the yields on the irrigated and non-irrigated plots under both methods of planting were essentially the same (Figure 2). This conforms with the results obtained during 1948 at the same planting date.

Comparison of Surface Planting with Ridge-Cover Planting. There was no benefit to sugar production in 1948 from the use of the ridge-cover method of planting compared with the common or surface method of planting (Figure 1). The greatest differences in yields of sugar beets and sugar due to methods of planting occurred at the late planting date with sugar beets irrigated for emergence. These differences may have been due to the method of removing the ridges or to climatic conditions prevailing at the time the ridges were removed rather than to any inherent qualities of the ridge cover itself. The use of the harrow lengthwise of the plots was not entirely satisfactory. In some instances too much soil was removed and in others not enough. The ridges which were irrigated proved to be firm and more difficult to remove than those which were not irrigated. Despite these difficulties the ridge-cover method was essentially as effective as the surface method of planting. The ridge-cover method of planting did greatly facilitate the application of irrigation water at planting time.

In 1949 differences in yields of sugar beets due to planting method were significant (Figure 2). For example, differences in favor of surface planting over the ridge-cover method where irrigation was not applied at planting time were 2.24, 1.07 and 0.68 tons per acre and 702, 313 and 302 pounds sugar per acre for the three dates of planting, respectively. In contrast there was no consistent effect of planting method upon yields where irrigation was practiced at planting. Either providing moisture by irrigation at planting time or conserving moisture by the use of a ridge cover for sugar beet seed

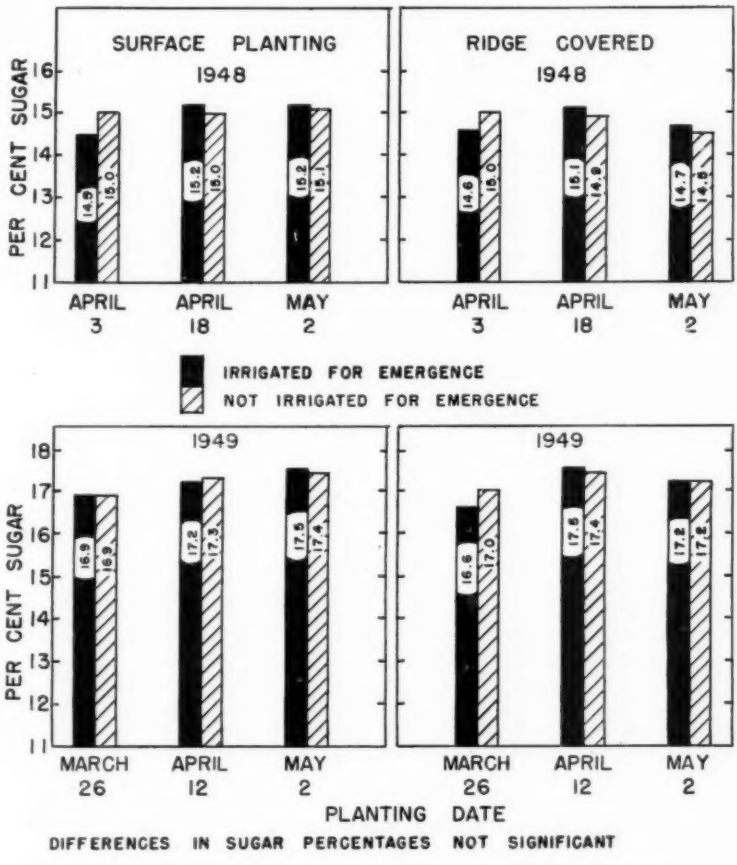


Figure 4. Influence of planting date, planting method and irrigation for emergence on the sugar content of sugar beets. 1948 and 1949.

planted March 26, 1949, proved to be unfavorable practices. Explanations for the contrasting results obtained in 1948 and 1949 have been presented.

Stands of Sugar Beets

In 1948 the poorest stands were obtained at the late planting date (Figure 3). The smallest stand was 66 per cent with the ridge-cover method planted May 2 and irrigated for emergence. The largest stand was 89 per cent for surface planting on April 18 and irrigated for emergence. The trends in stands during 1948 correspond in a general way with the yield trends shown in Figure 1.

In 1949 a great reduction in stand occurred for sugar beets planted March 26 compared with plantings made April 12 and May 2 (Figure 3). This reduction in stand was due to a severe frost on the night of April 15 which killed many of the sugar beet seedlings. The largest stand for the March 26 planting was 62 per cent with the surface planted sugar beets which were not irrigated for emergence. Compared with the irrigated surface planted sugar beets and the ridge-covered sugar beets, fewer of the seedlings were near the surface of the ground and in danger of frost on April 15. Consequently, a better stand was obtained. The stands obtained in 1949 in general correspond with the yield trends shown in Figure 2.

Sugar Content of Sugar Beets

The three factors studied in this experiment during 1948 and 1949 failed to influence the sugar content of sugar beets significantly (Figure 4). During 1948 the sugar content of beets from all treatments was approximately 15 per cent compared with approximately 17 per cent in 1949. As a result, the yields of sugar per acre in 1949 were considerable higher than in 1948.

SUMMARY

A three factor experiment dealing with the production of sugar beets was conducted at the Scotts Bluff Substation in western Nebraska during 1948 and 1949. The three factors studied comprised date of planting, method of planting, and irrigation for emergence at planting time. During 1948 the sugar beets were planted April 3, April 18 and May 2. During 1949 the three planting dates were March 26, April 12 and May 2. Two methods of planting were used at each planting date: (a) surface or regular planting of sugar beets, and (b) surface planting with a ridge cover. Irrigation for emergence was practiced on one-half of the plots in each planting method at each planting date.

In 1948 a marked decline in yield of sugar beets occurred with a delay in planting date where the sugar beets were irrigated for emergence. However, where the sugar beets were not irrigated for emergence differences in yield due to planting date were small. In contrast to the results obtained in 1948, yields of sugar beets in 1949 for the medium and late planting dates were significantly higher than the yields of sugar beets planted March 26. The latter results were due in a large measure to frost injury to the early planted sugar beets as they emerged.

Irrigation at planting of sugar beets compared with no irrigation at planting in 1948 resulted in a large increase in yield at the early planting date, a moderate increase in yield at the medium planting date, and no increase in yield at the late planting date. In 1949, however, irrigation for emergence at the early planting date resulted in a significant decrease in yield of surface planted sugar beets and a small but nonsignificant increase in yield of sugar beets planted with the ridge-cover method of planting. These contrasting results for irrigation at planting in 1949 were attributed to differences in stand which were a consequence of the variable effect of

planting method and irrigation practice upon frost damage. The influences of irrigation for emergence on yields of sugar beets at the medium and late planting dates were similar in 1948 and 1949.

Essentially the same yields of sugar beets were obtained for the ridge-cover and surface methods of planting in 1948. However, where irrigation was not practiced at planting in 1949, the surface method of planting was distinctly superior to the ridge-cover method of planting. An explanation was presented.

Stands of sugar beets obtained during 1948 and 1949 conformed in a general way to the yield trends from the various treatments.

The three factors studied did not influence the sugar content of sugar beets during 1948 and 1949.

Some Seed-Soil Moisture Studies with Sugar Beets[1]

J. R. HUNTER AND S. T. DEXTER[2]

In agricultural practice, soil moisture is rarely optimal for sugar beet (Beta vulgaris) seed germination and emergence. Experience as well as controlled experiment (2)[3] has shown that in sugar beets germination is slow at low soil moisture contents, when other seeds may be germinating well. A number of investigations (1, 3, 4) have proposed various reasons for this and have indicated that probably one of the most critical conditions is that of the moisture relationship between seed and environment. It was, therefore, the purpose of this study to examine some of the specific moisture requirements of sugar beets for germination, to determine experimentally what the optimum and the critical conditions for germination might be and to establish some sort of time schedule for the various phases of water uptake and germination.

Experimental Procedure and Results

Segmented seed (US 215x216) screened through 8/64" mesh on 1/12" mesh screens were used in all experiments. The soil was a Brookston clay loam taken from the plow layer of the College farm at East Lansing, Michigan. All experiments were carried out at approximately 70°-75° F.

Experiment I. In a series of mason jars, air was maintained at a variety of relative humidities (25, 50, 60, 65, 70, 75, 80, 90, 100%) by placing in them various concentrations of H_2SO_4 as indicated by Wilson (5). Suspended from the inside of the jar cap and above the liquid in the jar was a small perforated metal cup. Within this cup was placed a known number of air dry seed of a known moisture content. At varying intervals these seeds were removed from each of the air tight jars, weighed and returned. When the weight became constant, indicating moisture equilibrium between the seeds and the surrounding atmosphere, the seeds were placed in an air-oven at 102° C. for 24 hours and reweighed so that their moisture contents could be calculated. Table I shows the results of this experiment.

TABLE I. Moisture content of sugar beet seeds exposed for various periods of time to air at the relative humidities shown (75° F.).

Time in Hours	Percentage moisture content of seeds. Relative Humidity of Atmosphere in Jars								
	25%	50%	60%	65%	70%	75%	80%	90%	100%
0	5.74	5.74	5.74	5.74	5.74	5.74	5.74	5.74	5.74
24	6.03	8.12	7.75	9.83	12.10	11.65	11.99	18.33	25.18
48	6.13	9.23	8.57	10.60	12.56	13.65	13.35	19.48	27.95*
168	6.73	9.63	9.02	11.03	13.21	13.96	14.07	18.65*	28.82*

*Indicates that the seeds became very moldy.

[1] Approved for publication by the director of the Michigan Agricultural Experiment Station as Journal Article No. 1,139.

[2] Graduate Research Assistant and Professor (Research) Respectively, Michigan Agricultural College Experiment Station.

[3] Numbers in parentheses refer to literature cited.

In no case was there any germination of the seeds. From the table it can be seen that at every relative humidity the seeds approached equilibrium in about 48 hours. Seed lying in soil too dry for germination should therefore approximate its maximum moisture content in about 48 hours, and should never exceed about 29% moisture content.

Experiment II. A 200-gram sample of the Brookston soil (through 10/64" screen) was placed in each of a series of mason jars and brought up to the following range of moisture contents (8, 10, 12, 14, 16, and 18%) by adding appropriate amounts of water and mixing with a spoon. There were seven jars for each moisture content. The jars were then closed and the soil was allowed to come to equilibrium over a period of three or four days. During this time the jars were shaken two or three times a day. Air dry seed of known moisture content was then added to the soil in each of the jars. The soil was not packed around the seeds. At intervals shown in Table II, a jar at each moisture content was opened and the moisture content of the seeds therein was determined.

The specific purpose of this experiment was to determine how readily the seeds could obtain moisture from soils of different moisture content. Table II shows the results.

TABLE II. Percent moisture reached by sugar beet seeds after various intervals in contact with Brookston soil at the moisture contents shown. (75° F.)

Time in Hours	Percent moisture in seed in soil at various moisture contents Moisture content of the soil					
	8%	10%	12%	14%	16%	18%
0	7.03	7.03	7.03	7.03	7.03	7.03
½	15.00	17.80	19.75	21.00	17.80	20.19
1	19.62	22.35	15.05	23.75	21.80	22.37
1½	19.42	23.64	23.94	25.53	24.32	24.97
2	20.02	24.57	24.98	24.17	22.40	27.48
4	21.86	26.24	29.80	31.38	31.84	28.78
24	22.07	24.95	29.87	32.53	33.04*	34.99*
48	20.70	25.83	29.90	32.94*	33.64*	35.78*

*Seeds beginning to sprout.

This experiment was not carried out past 48 hours as the results of Experiment I indicated that within that period of time the seed should have come to equilibrium with its environment. Results here indicate that when in contact with soil, irrespective of its moisture content, the seeds had practically attained equilibrium after a period of four hours and that by 48 hours those seeds in the soils of higher moisture content had already begun to sprout. Apparently, films of free water (14-18%) on the soil particles can supply moisture to the seeds more rapidly (4 hrs. vs. 48 hrs.) than can saturated air (100% R. H.), and, in addition, can bring the seeds to moisture contents sufficiently high for germination. In soils with a moisture content of 12% and lower, the seeds appear to have exhausted the soil's moisture supply at the end of 4 hours and do not subsequently become more moist. This suggests a break in the capillary supply system particularly at 12% and that in the soils at 8 and 10% the relative humidity of the soil air is between 90 and 100% relative humidity (compare with Table I).

Experiment III. Seed of known moisture content was immersed into a beaker of H_2O at 75° F. Samples were removed at appropriate time intervals for moisture content determination until equilibrium was attained. The purpose of this experiment was to ascertain the rate at which sugar beet seeds could take up water when completely surrounded by water. Table III shows the results of this experiment.

TABLE III. Percent of moisture in sugar beet seeds after various periods of immersion in water.

	Length of time in direct contact with water, in hours							
	0	½	1	1½	2	4	24	48
Moisture Content	7.03	41.38	40.44	43.13	42.57	48.92	50.20	51.65

The results indicate that within the first four hours the seed became almost completely saturated with water. During the first half hour of soaking, the seeds absorbed water very rapidly and to a percentage definitely higher than that required for germination (see Exp. II). Periods of time required to reach a moisture content of approximately 30% would then be about 48 hours in air at 100% relative humidity, 4 hours in loose contact with damp or moist Brookston soil and ½ hour in water.

Experiment IV. A series of mason jars was made up with Brookston soil of varying moisture content as in Experiment II. In this case the range was 10, 12, 14, 16, 18, 20 and 22% moisture. For each different moisture content ten jars were prepared. Ten lots of seed were made up, with moisture contents of 5, 7, 10, 14, 18, 20, 22, 26, 30 and 35%. In each of the jars ten seeds were planted at ½ inch depth by pouring a measured amount of loose soil on top of the seeds. The soil was not packed around the seed. The moisture content of the seed planted in each jar of a series was different so that for each different soil moisture there was a complete range of seed moistures. Rates of germination were observed.

Due to lack of space the results of only two seed moistures (5 and 14%) will be presented. These two particular moisture contents were chosen as 5% approximates the moisture content of air dry seed and 14% approximates that of seed stored at a relative humidity of 75-80% (see Table I), which is the maximum for safe storage. Figures indicate the number of sugar beet seeds germinated in the different soils at varying times after planting. In soils at 22% moisture, seeds were drowned and no sprouts appeared.

Experiment V. Flats of Brookston soil were prepared so that each contained at the beginning of the experiment the same amount of soil of the same moisture content (11.8%). Seeds of known moisture content (5.24%) were planted therein at half inch depth in separate rows. There were ten seeds to each row and the rows were 22 inches long. There were 5 rows for each treatment, which consisted of the following: Following the planting, water was applied from a pipette to the surface of the soil over each of the rows of seeds in the following amounts: 0, 5, 10, 15, and 20 cc. per row. 10 cc. per row would amount to approximately 25 gal. per acre. Rates of emergence following these treatments were noted. In order to insure a more constant moisture content of the soil in the flats during the experiment, they were placed in the basement of the greenhouse, which has a relative humidity of about 80%. Table V indicates the results obtained.

In this soil, at a critical moisture content, a small amount of water in contact with the seed gave marked acceleration in emergence. Since the seeds were about 2" apart, most of this water was probably wasted. It seems likely that one drop of water directly on each seed would have been highly effective in producing rapid emergence, and that the amount per acre could have been reduced to a matter of a few quarts.

TABLE IV. Number of sprouts emerged after the periods shown, when seeds of 2 moisture contents were planted in soils of various moisture contents.

Time after Planting	Soil Moistures 10%		12%		14%		16%		18%		20%	
	Seed Moistures 5%	14%	5%	14%	5%	14%	5%	14%	5%	14%	5%	14%
24 hrs.	0	0	0	0	0	0	0	0	0	0	0	0
48 hrs.	0	0	0	0	1	2	1	2	3	4	2	4
72 hrs.	0	0	0	1	2	4	4	3	5	7	5	6
96 hrs.	0	0	2	3	3	6	7	8	8	8	8	10
120 hrs.	0	0	3	5	6	8	8	9	9	10	10	10
144 hrs.	0	1	3	6	8	9	9	9	9	10	10	10
168 hrs.	0	1	4	8	9	10	10	9	9	10	10	10

Discussion

From the results of these experiments it may be seen that in a Brookston soil air dry seeds germinated only between 12% and 20% soil moisture. Seeds did not germinate in air in relative humidities of even 100%. At this relative humidity the seeds themselves attained a value of almost 29% moisture. This leads one to conclude that unless the seed can absorb enough moisture to raise its moisture content above 29% it will not germinate.

Now, the relative humidity of the vapor pressure of the water in soils of 12, 14, 16 or 18% moisture content is 100%. It may therefore be reasoned that the seed which sprouted in soils of those moisture contents was able to draw water from some other source than the soil atmosphere. In other words, germination depended upon the seed coming in contact with some surface of free water. However, too great an amount of free water about the seed for a period of several days inhibited germination as it limits the amount of air that the seed may absorb.

TABLE V. Number of seeds germinated (out of 50 planted) at various intervals after planting under various treatments.

Time after Planting	Soil treatment—amount of water per row				
	No water	5 cc.	10 cc.	15 cc.	20 cc.
24 hrs.	0	0	0	0	0
48 hrs.	0	0	1	5	7
72 hrs.	1	1	2	16	20
96 hrs.	3	3	5	21	36
120 hrs.	5	8	14	35	40
144 hrs.	5	15	27	45	48
168 hrs.	7	21	32	47	48

Once in contact with free water surface, seeds were able to absorb water rapidly. Their moisture content was increased, on soaking in water, from an air dry condition (about 5% moisture) to one favorable for germination (about 35% moisture) in half an hour. In damp soil this required about 4 hours. Thus seeds absorbed quickly free or capillary moisture with which they were in contact. It would appear that only that water which was in the seed or which was in free films within a relatively small radius was instrumental in actually effecting germination.

Summary

1. Seeds failed to germinate in air at 100% relative humidity. At this high humidity a maximum of 29% moisture was absorbed.

2. In the Brookston clay loam germination did not occur unless the seed took up somewhat over 30% of moisture. Germination took 24 hours or more, but water absorption was complete in about 4 hours.

3. Seeds immersed in water took up over 30% of water in one-half hour.

4. Free water films appeared to be necessary for germination.

5. In soils near the lower critical moisture content for germination, planting seeds of higher moisture content speeded up emergence and adding small amount of water in contact with the seed, induced germination even in soils drier than the critical point.

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Physiology of Growth, Sugar Accumulation and Mineral Intake of Sugar Beets[1]

M. M. AFANASIEV, H. E. MORRIS AND E. E. FRAHM

Preliminary Report

Physiology of growth, accumulation of sugar and mineral content of tops and roots of sugar beets were studied during 1948 and 1949 in six continuous beet plots at Huntley Branch station, Huntley, Montana. These six plots were fertilized since 1942 with the following amendments: Plot 2e was fertilized with phosphorus, nitrogen and manure, plot 2d with phosphorus and manure, plot 2c with nitrogen, plot 2b with manure and plot 2a with phosphorus. Plot 2 was not fertilized and was used as a check. On an acre basis, manure was applied at the rate of 12 tons, nitrogen at 125 lb. as ammonium sulphate and phosphorus as treble superphosphate at 125 lb.

Data pertaining to the physiology of growth, sugar determinations and quantitative measurement of nitrate nitrogen and acid soluble phosphate phosphorus in the petioles were made nine times during the growing season. Quantitative chemical analyses of sugar beet roots and tops for N, P, K, Ca and Na were made three times during the growing season. The soil of each plot was analyzed for available phosphorus four times during the growing season.

Readings of diseases in all these plots were made several times during the growing season.

The effect of soil fertilization was correlated with the growth of beets, sugar and mineral composition and the disease situation in these plots.

The results obtained during this investigation indicate that the growth of beets and their physiology were quite different in relatively poor (2, 2a, 2c) and good (2b, 2d, 2e) plots.

The ratio in weight of sugar beet roots between the poorer and better plots as determined in the first part of August was equal to 1:2.6 in 1948 and 1:2.4 in 1949. These same ratios remained approximately constant until harvest time.

The results indicate that, when beets emerge about May 15, their roots should weigh at least 0.5 pound each by the first part of August to produce a good yield.

The greatest development of beet tops in the better plots occurred from thinning to the middle of August. In the poorer plots the tops of the sugar beets made a gradual growth throughout the season and always remained relatively small.

The ratio in weight of tops of beets in the poorer and better plots was equal to 1:3, as determined in the middle of July and August in both years.

[1] Contribution from Montana State College, Botany and Bacteriology, and Chemistry Departments, Agricultural Experiment Station, Paper No. 232, Journal Series.

Toward the end of the growing season the tops of the beets showed a decrease in weight in all plots.

The results show that good size of tops early in the season is a very important predisposing factor for good ultimate performance of the crop. According to the results, it appears that, when beets emerge approximately May 15, their tops should weigh on an average at least a half pound each by the middle of July and a pound by the middle of August in order to produce good yields.

Beets grown in all plots showed the highest number of leaves during August. The number of leaves did not change a great deal after reaching a maximum and in most cases decreased slightly toward fall. The ratio between averages of the number of leaves developed by beets in poorer and better plots was equal to 1:1.8 in 1948 and 1:1.5 in 1949 as determined in the first part of August. The same ratio for the maximum of leaves produced by beets at any time during the growing season was equal to 1:1.3 for poorer and better plots for both years.

These figures show that the number of leaves which beets develop is also a significant factor for judging the ultimate performance of a crop.

Beets grown in all plots in both years showed the maximum development of leaf area by the middle of August. Then the area of leaves decreased gradually toward fall. The ratio between the averages of leaf areas developed by beets grown in poorer and better plots was equal to 1:1.6 in 1948 and 1:1.4 in 1949 as determined in the first part of August. The same ratio for the maximum of leaf area developed by beets at any time during the growing season was equal to 1:1.3 in 1948 and 1:1.5 in 1949.

Variations in size of leaves of beets grown in poorer and better plots are quite similar to those in number of leaves.

In judging top to root ratios of beets, it is considered that 35 to 40 per cent for tops and 60 to 65 per cent for roots is a good proportion for beets at harvest time. On this basis beets grown in plots 2, 2a, 2d and 2e (Check, P, PM, and NPM respectively) had more favorable top to root ratios than beets grown in plots 2b (M) and 2c (N). The tops of beets grown in the last two plots were proportionately too heavy in comparison to the roots. Apparently continuous fertilization with manure and nitrogen created in the soil some excess of nitrogen or deficiency of available phosphorus or both.

The percentage of sugar in beets increased rather rapidly until the end of July; then the sugars increased at a rather slow rate and especially during September. The greatest differentiation in percentage of sugar in all these plots during both years usually occurred during the early part of growth. During the first part of August beets grown in better plots showed at least two per cent less sugar than those grown in poorer plots. At the end of the growing season the percentage of sugar was about the same in all plots.

The occurrence, during the first half of the growing season, of a higher percentage of sugar in beets grown in poorer plots as compared to those grown in better plots can be used as a factor of negative correlation with the final production of beets.

Chemical analyses of tops and roots of sugar beets for nitrogen, phosphorus and potassium showed that the percentages of these elements in tops and roots of beets follow closely the productivity of soil and the ultimate yields of beets. It is difficult to establish a similar type of correlation for sodium and calcium.

Colorimetric tests of sugar beet petioles for phosphorus showed that generally beets grown in better plots had a higher percentage of phosphorus than those grown in poorer plots. Analyses of beet petioles for nitrogen have not been completed.

Soil analyses for available phosphorus showed that the soils of plots 2 (check) and 2c (N) had the lowest amount of phosphorus in both years. The soils of the remaining plots (2a (P), 2b (M), 2d (PM) and 2e (NPM)) with some exceptions showed a fairly good supply of available phosphorus.

More seedling diseases and fusarium yellows of beets occurred in beets grown in poorer plots than in those grown in better plots.

Soil Compaction and Tillage Operation Effects on Sugar Beet Root Distribution and Seed Yields[1,2]

RAY A. PENDLETON[3]

INTRODUCTION

Numerous studies have been made of the relation of soil aeration to size and shape of sugar beet roots when grown for sugar production. Less attention has been given to the subject where the beets are grown for seed. Proper air-water-nutrient proportions in the soil are critical factors in plant growth. Suitable tilth or soil structure, which to a considerable extent controls aeration, is perhaps of greater importance where the root is the desired product than where the top of the plant is the crop. However, good soil aeration is necessary for good root distribution and normal top growth could not be expected if the feeder roots could not function properly.

Various expressions such as granular, crumb, porous, etc., are used to designate good soil tilth or good structure. The depth to which plant roots penetrate will be determined by the plant type and the physical limitations of the soil. Compact layers such as hard pans, plowsoles, or water logged may be partially or completely impervious to certain types of roots.

The pore space of soils, that portion not actually filled with solid material, may be differentiated as capillary and non-capillary depending on the size of the pores. Soils vary widely in their total as well as non-capillary porosity. The capillary portion would be filled with water under conditions of field capacity moisture. The non-capillary portion, i.e., the size of the pores as well as total porosity, is important in aeration. The major influencing factors are soil texture, organic matter content and soil tilth. The texture is more or less fixed by the soil formation processes and cannot be changed. Organic matter content and tilth are subject to manipulation. The proportion of non-capillary pore space necessary for good growth may vary considerably with different soils.

In the Willamette valley it has frequently been observed that the main tap roots of sugar beets tend to branch or turn abruptly (Fig. 1) after penetrating the soil to a depth of 2 to 4 inches. In occasional instances the main tap root was found to grow laterally for a distance of several feet

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[2] Published as Technical Paper No. 619 with the approval of the Director, Oregon Agricultural Experiment Station, and Chief, U. S. Bureau of Plant Industry, Soils and Agricultural Engineering, on the basis of research cooperatively conducted.

[3] Agronomist, Div. of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, USDA Field Station, Corvallis, Oregon. Work done in cooperation with Oregon Agricultural Experiment Station.

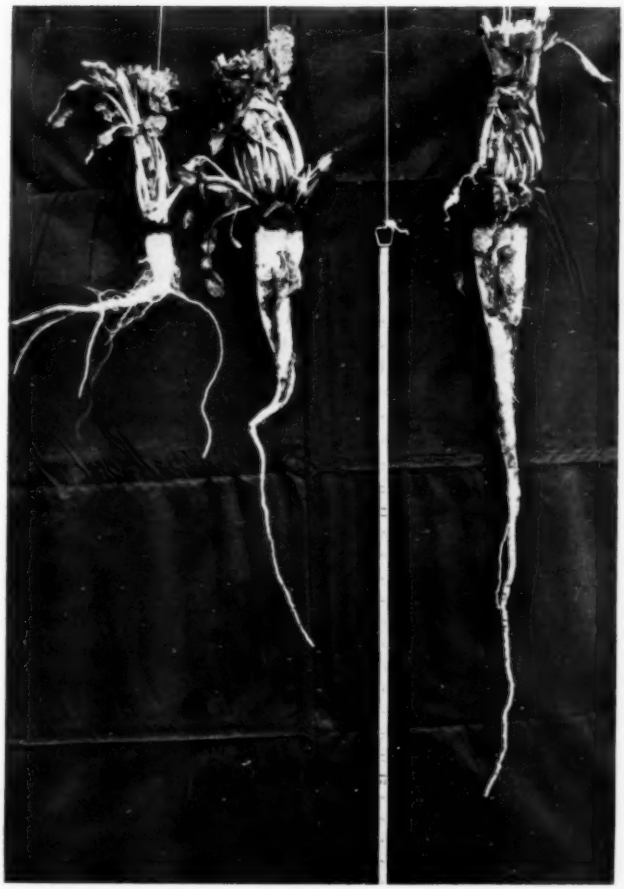

Figure 1.
Left: Root turned abruptly at about 2" depth, typical of many plants in this area.
Center: Result of restricted penetration at about 6" depth.
Right: Normal growth.

without penetrating the soil to a depth of more than 2 to 3 inches. If the feeder roots follow a similar pattern, they would be subject to injury from even shallow cultivation and to desiccation in periods of low rainfall. However, shape of the root, which is highly important for tonnage yields, may be much less significant where only the seed is harvested.

Willamette silt loam soils used for sugar beet seed production have shown 45 to 55 per cent total and 7 to 20 per cent non-capillary porosity. Chehalis sandy loam soils have a similar wide range of pore space. Impeded root development indicating poor tilth has resulted frequently with sugar beets in these Willamette valley soils. Samples of Medford loam soils from southern Oregon showed a relatively low range of 44 to 48 per cent total porosity but proportionally high non-capillary porosity. In none of the Medford soils studied has there been any tendency toward restricted sugar beet root development.

LITERATURE REVIEW

Baver (1) states that the ideal soil would have about half the total pore space as non-capillary. Farnsworth and Baver (2) in studying one of the clay soils of Ohio found high total porosity but relatively low non-capillary porosity. They concluded that for good sugar beet growth the non-capillary porosity should be about 8 to 10 per cent. Below 8 per cent both yields and stand of beets dropped off sharply. Corresponding values of 15 to 20 per cent have been suggested for some European soils. Farnsworth and Baver further found that soils which had become compacted by tillage often had non-capillary pore space values as low as 2 to 4 per cent. Considerable improvement in structure was obtained in their work by incorporating 20 tons of manure per acre and further improvement by soil ridging.

Stephenson and Schuster (4) in investigating some orchard soils in Oregon found 44 to 48 per cent total porosity and 11 to 17 per cent non-capillary porosity in a sample of Willamette silt loam. The same authors found for a sample of Newberg loam about 54 per cent total and 15 per cent non-capillary porosity in the surface 6 inches. They reported greatly decreased pore space in cultivated orchards as compared to non-cultivated. A sample of uncultivated Newberg silt loam which they were investigating had 64 per cent total and 30 per cent non-capillary porosity. Under cultivation this was reduced to 50 and 3 per cent respectively. Powers (3) noted 52.5 per cent total and 21.0 per cent non-capillary porosity in a sample of Chehalis fine sandy loam.

Veihmeyer and Hendrickson (5) working with some California soils made compaction tests on soils of the Bale, Yolo, and Madera series on which sunflowers were grown as the test crop. They found no growth of roots in Bale and Yolo soils when compacted to a density of 1.8 and only a minor amount of root growth in the Madera soil with a density of 1.75. However, they found that roots seemed to extract water about normally from a Holland soil when compacted to a density of 1.8.

METHODS OF INVESTIGATION

Field Experiments

In 1947, field trials were made with four tillage operations and two rates of manure, and in 1948, six tillage operations were used to determine their effect on soil pore space and tap root penetration. The tillage operations were in randomized block design with 6 replications. In both 1947 and 1948, the tillage operations consisted of: (1) shallow spring-toothing,

(2) duck foot shovels operated about 8 inches deep, (3) chisel points operated 8 to 9 inches deep directly beneath the row location, in 24-inch spacing, (4) rotary tillage to a depth of 8 to 9 inches. In 1948 only, there were two additional operations of: (1) shallow discing and rolling, and (2) chisel points operated 8 to 9 inches deep on 12-inch spacing. Where the chisel points were used the fall fertilizing was placed at the bottom of the tillage before seeding. In all other operations the fall fertilizer was side dressed at the first cultivation.

TABLE 1. Effect of Tillage and Manure Treatment on Pore Space of Chehalis Sandy Loam Soil.

Tillage treatment	Soil depth	Pore space in soil		
		fall	Total spring	Non-capillary spring
	(inches)		(percent)	
1. Shallow springtoothing	1-3	51.2	47.2	8.2
	4-6	49.0	44.7	5.7
	6-8	47.7	44.2	5.2
2. Rotary tilled	1-3	53.2	52.0	13.0
	4-6	52.7	52.0	13.0
	6-8	52.2	51.0	12.0
3. Rotary tilled following tractor wheels	1-3	.....	48.0	9.0
	4-6	.....	47.2	8.2
	6-8	.....	49.0	10.0
4. Manure at 10 tons/acre	1-3	.....	52.6	13.6
	4-6	.....	50.6	11.6
	6-8	.....	46.8	7.8
5. Manure at 10 tons/acre following tractor wheels	1-3	.....	49.0	10.0
	4-6	.....	49.6	10.6
	6-8	.....	46.0	7.0
6. Manure at 100 tons/acre	1-6	.....	54.5	14.5

For the spring fertilizer treatment, the tillage plots were divided and on one portion the spring fertilizer was broadcast and irrigated into the soil, while on another portion the fertilizer was side dressed at 4 to 5 inches deep.

Tests for porosity were made for some of the treatments in the fall and again in the spring. The spring tests were made both in the wheel tracks of the cultivating tractor and in the row where there were no tracks. Only spring tests were made for the manure plots since this product would not be expected to produce an immediate effect.

Greenhouse Trials

With a view to determining what degree of compaction in these soils would prevent sugar beet root development, Chehalis sandy loam was placed in greenhouse pots and compacted by hand tamping small portions at a time to make the whole mass as uniform as possible. Conditions were made for total porosity of 42.5, 45.5 and 53.5 per cent respectively. This represented

approximately 3.5, 6.5, and 14.5 per cent non-capillary porosity, or a density of about 1.95 for the most compact condition and 1.85 for the medium compaction. Similar pots were filled with Willamette silt loam and tamped to provide four degrees of porosity of about 46.5, 50.7, 57.2, and 62 per cent. These represented respectively about 7.5, 11.7, 18.2, and 23 per cent non-capillary porosity. Five replications of each treatment were made. Beet seed was planted on the surface of the soils, covered lightly with sand and permitted to germinate. A single plant was grown in each pot to a size of one-half to 1 inch diameter of the main root. The pots were then dumped and the soil carefully washed away to expose the root systems. Figure 2 shows some of the conditions observed.

EXPERIMENTAL RESULTS

Field Trials

Porosity studies—The rotary tillage treatment was especially helpful in relieving soil compaction in the surface 8 inches and provided conditions for excellent root penetration and distribution to this depth. Beet top growth was noticeably better on this treatment than on the shallow worked soil during the fall growing period. Deep chiseling directly under the row with the fall fertilizer placed at the bottom was only slightly less effective than rotary tillage. The better tilth of the rotary tillage treatment persisted through the winter rains.

Manure at 10 tons per acre disced into the surface provided good tilth in the surface 3 to 6 inches but the effect did not extend much deeper. This treatment made very little difference in the fall growth of beets. Manure at 100 tons per acre improved the tilth to a depth of 6 inches or more. Beets made very good fall growth on this, probably due to the extra nitrogen carried by such a large quantity of manure.

Driving tractor wheels over the rotary-tilled soil when in moist condition resulted in compacting the surface 3 to 6 inches to about the original tilth. However, the 6 to 9 layer remained in good condition following such compaction. Table I gives some data on porosity in these soils under the different tillage treatments.

Seed yields—All of the deeper tillage treatments which provided better soil aeration resulted in some improvement in seed yield. This effect was a little more obvious in 1947 than in 1948, as shown in Table II. Differences in seed yield from the manure plots would, of course, be influenced by the extra fertilizer value of the manure and consequently would not be a measure of the effect of this material as a soil conditioner. None of the tillage treatments resulted in severe compaction of the surface soil or serious inhibition of root penetration. However, such small yield differences as were obtained indicate the desirability of deep tillage for this crop.

Placing the fall fertilizer at the bottom of the 8-inch tillage cut directly under the row location resulted in better early fall growth of the beets but not in seed yield.

In the 1948 season, deep side dressing of the spring fertilizer produced about 8 per cent, or 200 pounds more seed per acre, than the same amount

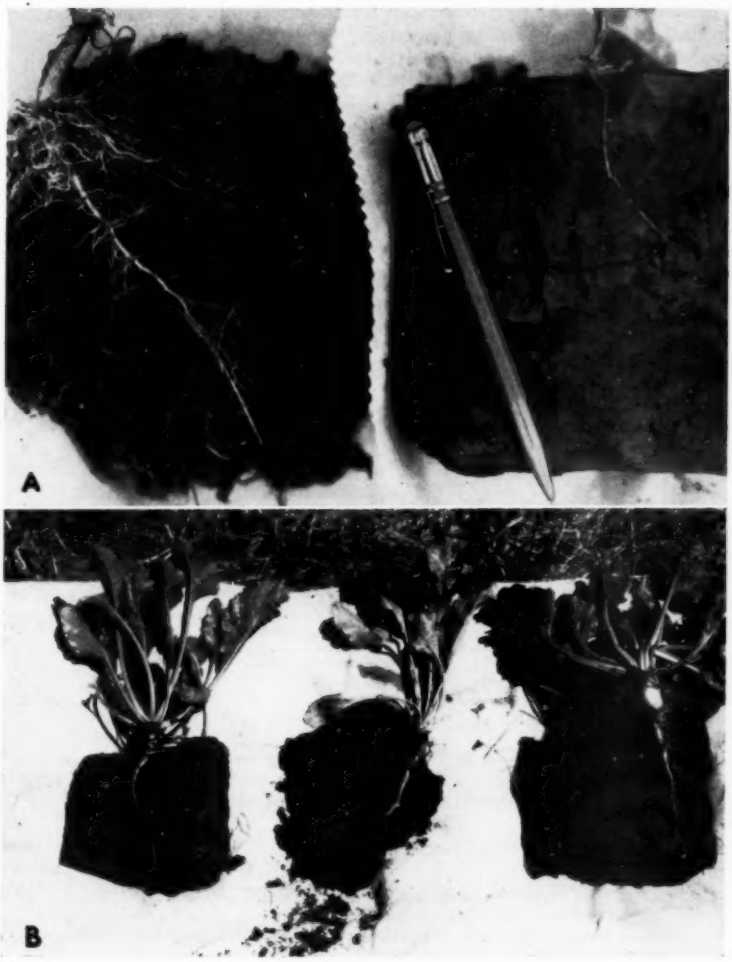

Figure 2.

A. Left: Root development in Willamette soil 62.5% total porosity. Right: Root development with only 46.5 percent total porosity.

B. Left: Beet root development in Chehalis soil with 45.5% total porosity.

Center and right: Root development with 53.5 percent total porosity.

of fertilizer broadcast on the surface and irrigated into the soil. Differences in seed yield due to fertilizer placement were less in 1947.

Greenhouse trials

Where either Chehalis or Willamette soil was compacted to a density of about 1.95 no roots penetrated it. Under medium compaction of density of about 1.8, the main tap root usually penetrated through the soil mass but there was very little feeder root development. With about 14 per cent noncapillary porosity for the Chehalis and 18 per cent for the Willamette soil and with density around 1.5, root penetration and distribution seemed to be unrestricted. The greater porosity of about 23 per cent non-capillary space in the Willamette soil did not materially further improve root growth. This condition was difficult to maintain with surface watering.

TABLE 2. Seed Yields Obtained with Varying Tillage and Fertilizer Placement Conditions.

	Seed per acre			
	1947		1948	
	Spring fertilizer placement			
Tillage treatment	Broadcast	Side dressed	Broadcast	Side dressed
	(pounds)			
1. Shallow springtoothing	1,348	1,335	2,460	2,640
2. Disced and rolled	------	------	2,500	2,740
3. Duckfoot shovels at 8" deep	1,580	1,751	2,560	2,820
4. Chisel points 8" deep	1,677	1,741	2,510	2,710
5. Rotary tilled 8" deep	1,405	1,553	2,660	2,890
6. Manure at 10 tons/acre	1,610	1,694	------	------
7. Manure at 100 tons/acre	------	2,043	------	------
Placement means	1,525	1,614	2,538	2,760
Diff. for significance between placement means at 5% odds.		166		67
Diff. for significance between tillage means at 5% odds.		317		143

SUMMARY AND CONCLUSIONS

Chehalis sandy loam soil which had been compacted by conventional tillage operations to a point of only about 5 per cent non-capillary porosity in the plow depth could be improved considerably by deep tillage or with heavy applications of barnyard manure.

Results were characterized by better shaped tap roots, faster fall growth and a little improvement in seed yields.

Rotary tillage to 8 inches deep, duck foot shovel tillage to the same depth, or chisel points directly under the row were about equally effective in improving shape of tap roots and increasing seed yields.

The small differences secured in seed yields suggest that the shape of the main beet root is not as important for seed yields as where the root is harvested for sugar.

Compacting Chehalis sandy loam soil in greenhouse pots to a non-capillary porosity of 3.5 per cent restricted all beet root development. Feeder root distribution and development was much better with a non-capillary porosity of 14 per cent than with only 6.5 per cent.

In Willamette silt loam soil, beet root development was restricted when the non-capillary porosity was 11.7 per cent but was good at 18 per cent. These figures would likely not characterize all soils of these series since the amount of organic matter and other factors might alter conditions.

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Tillage Practices and Sugar Beet Yields[1]

R. L. COOK[2]

Sugar beets produce the highest yields on the dark-colored soils which have been brought under cultivation recently. Over a period of years, growers have learned this through experience and gradually the areas of production have centered in those portions of the state where such soils prevail.

After many years of cropping, the soils in some areas have deteriorated until maximum yields are no longer possible. Even after the installation of dredge ditches and tile drains, and with the use of more and better fertilizers, yields continued to decline. Observations in some localities have indicated that the decline in yield may be due to poor aeration. Instances of better growth on ditch banks and poor growth where soils were puddled by excessive rains and improper handling were common.

These observations led to certain greenhouse studies which have shown that sugar beets are very sensitive to excessive soil packing and conditions of poor aeration.

In the meantime, an entirely new system of farming has been developed on sugar beet producing farms. Horses have been replaced by heavy tractors and heavier tillage implements have been designed to follow the tractor. Recently the heavy harvesting machinery has entered the picture. These changes have taken place during a period when the trend has been toward increased cropping and soil depletion, with consequent losses in organic matter, the ingredient which keeps heavy soils in a granulated condition.

Sugar beet growers have long been in the habit of working their soil into a fine, well-packed seed bed. It seemed that perhaps they were working their soils too much. Questions were being asked about rotary tillage with machines recently placed on the market. Accordingly, it seemed advisable to conduct some experiments with different types of tillage machines, particularly with the idea of finding out how much or how little tillage was necessary for sugar beets.

The results of some of the greenhouse experiments on aeration and three years of tillage work in the field are briefly reviewed in this paper.

EXPERIMENTAL METHODS

Greenhouse

Sugar beets, corn, soybeans, tomatoes, oats and wheat were grown in 4-gallon pots of normally and excessively packed soil. The cultures which were considered as normal were set up by simply pouring the air dry soil

[1] Contribution from the Soil Science Section, Michigan Agricultural Experiment Station, East Lansing, Michigan. Authorized for publication by the Director as Journal Article No. 1121 of the Michigan Agricultural Experiment Station.

[2] Professor of Soil Science. The field experiments reported in this paper were conducted jointly by the Sections of Soil Science and Agricultural Engineering. The writer thanks Dr. F. W. Peikert, former Professor of Agricultural Engineering, now Head of Agricultural Engineering at the University of Maine, for cooperative assistance in this work.

(Brookston clay loam) into the pots. In the packed cultures, the soil was moistened with an amount of water considerably less than moisture equivalent and was then tamped firmly into the jars. The moisture content was not sufficient to cause puddling. The degree of compaction was sufficient to increase the volume weight from 1.0 to 1.43. All of the cultures received 0-20-20 fertilizer and some of those excessively packed were given an application of ammonium nitrate when the plants first showed symptoms of nitrogen starvation. A picture of the effect of compaction on the biological activity within the soil was obtained by determining nitrate nitrogen and the degree of oxidation of the iron in the soil.

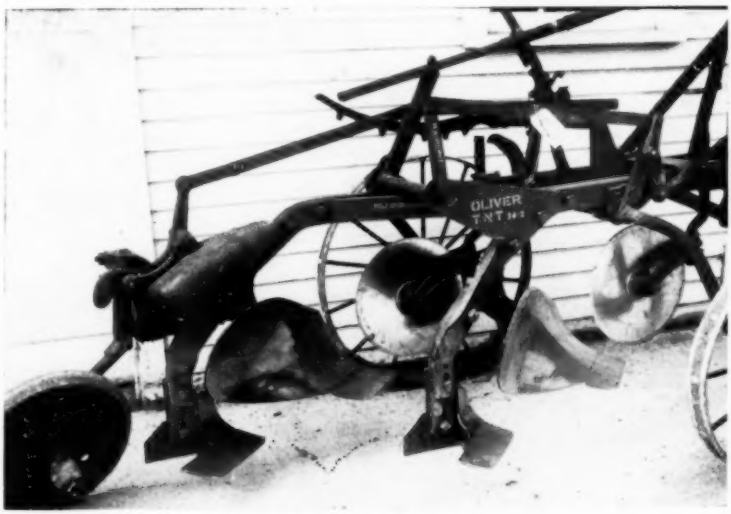

Figure 1. Plow with sub-bases.

Field

Tillage experiments were conducted on a Brookston clay loam in Tuscola county during 1947 and 1948, and on a Brookston loam in Gratiot county in 1949. Beets followed corn the first two years and grain in 1949. The different methods of tillage and the equipment used in the tests are described below. Except where noted, all plowing was to a depth of 6 inches.

Methods and Machines

Conventional plow: A two-bottom plow, followed twice over with a double-disk harrow and twice with a spring-tooth harrow.

Plow with sub-bases: A two-bottom plow with two sub-bases set to cut an additional 3-inch depth in the furrow turned by the upper bottoms (Fig. 1). The subsequent disking and harrowing was the same as for the conventional plow.

Conventional plow with plow-packer attached: In this treatment, the packer shown in Fig. 2 was attached to the conventional plow. Planting followed immediately.

Conventional plow with mulcher attached: The mulcher consists of a group of spring teeth between single cultipacker units. It was attached to the conventional plow as shown in Fig. 3. Again, planting followed immediately.

TABLE 1. The effect of excessive packing, with and without additional nitrogen fertilizer, on the yield of several crops in 4-gallon pot cultures.

Crop	Yield* per pot (av. of 3 replicates) Normal soil (gms)	Packed soil (gms)	Packed soil + nitrogen (gms)
Sugar beets	37.5	5.8	15.5
Tomatoes	30.6	8.7	23.9
Corn	77.0	43.6	81.0
Soybeans	45.2	23.2	32.0
Wheat	22.2	18.4	39.6
Oats	34.3	23.2	37.1

*Sugar beet yields were of fresh roots. The other weights were of dry tissue, corn just tasseled, tomatoes and soybeans at the early fruiting stage, and the grains at the blossom stage.

Rotary-type tiller: The machine used was a two-wheel walking type with flexible tines. The seedbed was prepared in 1947 and 1948 by going over the ground once with hook tines to a depth of 6 inches. In 1949, when beets followed grain, it was necessary to go over the plots twice, once with knife tines, then finally with the hook tines. The knife tines would not penetrate to the 6-inch depth. The soil was cultipacked before the beets were planted.

Vertical disk plow: This machine consists of five disks which turn as a unit. It was set to cut 44 inches wide to a depth of 6 inches. The subsequent soil preparation was the same as for the conventional plow method.

Auger type plow: The plowing mechanism consists of a spiral auger mounted horizontally and driven from the tractor power-take-off. The machine was designed to cut 28 inches but it was impossible to cut more than 20 inches without overloading a two-plow tractor. It was necessary to cover the plots twice with the machine and penetration was only to 4½ inches. A cultipacker was run over the plots before the beets were planted. As in the case of the rotary-type tiller, this was because the soil was too loose for immediate planting.

RESULTS

Greenhouse

Row crops were found to be more sensitive to excessive packing than were the grain crops, and of the row crops studied, sugar beets were the most sensitive. The sensitivity of sugar beets to excessive packing and poor aeration was shown strikingly in a recent publication by Smith and Cook.[2] Beets followed sweet clover in greenhouse jars. Soil compaction slowed up the growth greatly. Forced aeration was beneficial in both the normal and packed cultures.

Organisms play an important role in the effect of soil compaction on

[2] A detailed account of this experiment was published in the Soil Science Society of America Proceedings. 11: 402-406. 1946.

the growth of crops. The normally packed soil contained, just after the beets were planted, 42 ppm of nitrate nitrogen, while the excessively packed soil contained only 2 ppm. In both cases, forced aeration increased the nitrate content. Compaction had so completely excluded the air that the

Figure 2. Two-bottom conventional moldboard plow with plow packer attached, pulled by two-plow tractor.

nitrifying organisms were unable to function.

Another proof of poor aeration in the packed soil was the presence of ferrous iron, whereas, in the normal soil, all of the iron existed in the oxidized state. Over-watering of the packed soil caused further increases in its content of ferrous iron.

In another experiment, sugar beets were compared with 5 other crops. According to the data reported in Table 1, excessive soil packing was more injurious to beets than to any other crop. Tomatoes ranked close to the beets, however, and corn and soybeans seemed considerably more resistant to the injuries from excessive packing. Grains were not badly injured.

It was thought that additions of nitrogen to the packed soil might compensate for the lack of microbiological activity and stimulate the growth enough to make up for the injury caused by packing. As shown by the data, this proved to be true with corn, wheat and oats. With the other three crops the yields had apparently been depressed for reasons other than

TABLE 2. The effect of various methods of tillage on sugar beet yields

Tillage method	Yield per acre—tons		
	Brookston clay loam		Brookston loam
	1947	1948	1949
Conventional plow	9.4	13.0	13.8
Plow with sub bases	9.7	13.1	12.4
Conventional plow with packer	8.6	12.9	14.6
Conventional plow with mulcher			15.9
Rotary-type tiller	8.4	12.1	13.4
Vertical disk plow	9.0	12.9	13.6
Auger-type plow	6.7	12.1	.....

simply slow nitrogen availability. The sugar beets are shown in Fig. 4. Where normal soil produced yields of 37.5 grams per pot, the packed soil produced only 5.8 grams per pot. With plenty of nitrogen supplied, the yield on the packed soil rose to 15.5 grams per pot, less than one-half the yield obtained on normally packed soil without an additional nitrogen application.

The evidence obtained from pot tests that beets are very seriously depressed by excessive soil compaction agrees well with observations often made in the field where yields have been low during seasons of extra-heavy rainfall and where fields have been worked while the soil was too wet.

Field

The data reported in Table 2 show that no method of tillage was significantly superior to those which included the use of the conventional plow. This is particularly interesting since during the past few years so much has been said and written against the use of the old-fashioned moldboard plow and in favor of those methods of tillage which mix the vegetation with the surface soil.

There was some slight indication that, on the clay loam soils, the subbase plow was slightly superior to the conventional plow, but this trend did not continue on the Brookston loam in 1949.

The vertical disk plow did a fairly good job in fitting the soil for beets, as the yields indicate. However, weeds were more plentiful where the soil was fitted in this manner.

In general, rotary tillage methods have not been satisfactory. In 1947 the yield obtained from plots where the auger-type plow was used was very low and that from the rotary-type tiller plots was a full ton per acre less than the yield from the plots which were plowed and tilled in the conventional manner. In 1948 the yields which resulted from these two methods of tillage were equal and about a ton smaller than those from any of the other treatment plots.

In 1949 the auger-type plow was not used in the sugar beet experiments. The yield obtained where the rotary-type tiller had been employed was not significantly smaller than that from the conventional plots but more labor was necessary to eradicate weeds. This, of course, is a serious disadvantage.

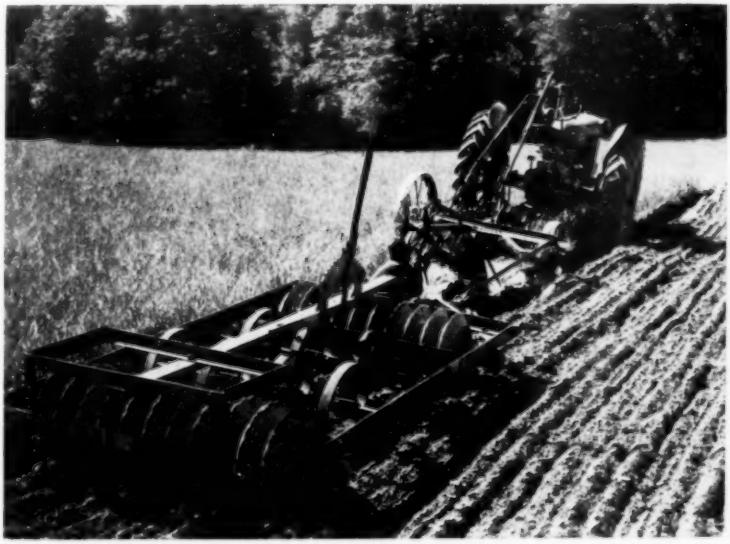

Figure 3. Two-bottom conventional moldboard plow with mulcher attached, pulled by two-plow tractor.

Of most interest in these results are the data obtained from the plots where the soil was plowed and fitted in one operation. In 1947 and 1948 this was accomplished with a conventional mold-board plow and the packer shown in Fig. 2. Planting followed immediately. The wheel width on the planter tractor was so adjusted that the tracks were left between the beet rows. Thus the beet seeds were placed in soil where the entire furrow slice was relatively loose. In 1947 the cultivating was done with a heavy tractor which so depressed the soil between the rows that some of the plants were destroyed. Thus the stand was injured and the yield somewhat decreased.

Mechanical injuries were avoided in 1948 by cultivating with a light tractor. A good stand resulted and the yield was just one-tenth of a ton under that obtained from the plots which had been disked and harrowed before planting.

The plots which received the two "once-over" tillage treatments produced, in 1949, higher yields than did any of the other plots. In fact, the mulcher plot yield was 2.1 tons per acre higher than that obtained where

the soil was fitted in the conventional manner. Close observations throughout the season correlated with the yield data. At all times the crop looked the best on those plots which had received the least pre-planting tillage.

With sugar beets, as well as with corn, beans, and oats, weed control has been easier on plots where the "once-over" tillage methods were employed. This was because weeds and grass were not pulled back to the surface where they could grow, and planting was done immediately, before weed seeds had time to germinate.

Figure 4. Sugar beets are injured seriously by excessive soil compaction. In pot 1 the soil was packed normally, while in pots 2 and 3 it was packed excessively. The beets in pot 2 received extra nitrogen fertilizer.

Weed seeds seem always to be present and every tillage operation or cultivation brings a new batch to the surface where they can obtain the air necessary for germination. When planting follows plowing immediately the crop seeds have at least an even chance of competing with the weed seeds. Observations made during these three years of tillage experiments have led to this conclusion.

SUMMARY AND CONCLUSIONS

Sugar beets, and several other crops, were grown in the greenhouse in normally and excessively packed clay loam soil. With all crops, yields were depressed by the excessive soil packing. Sugar beet yields were depressed more than were yields of other crops. Ferrous and ferric iron tests showed that aeration was poor in the packed soil. Nitrate nitrogen tests indicated slow nitrification in the packed soil.

The excessively packed soil cultures which had received additional nitrate fertilizer yielded as much corn, wheat, and oats as did the normally packed cultures. This was not true, however, with sugar beets, tomatoes, and soybeans.

During a three-year period, seven tillage methods were compared. The experimental results did not reveal any tillage method to be superior to those which included the use of the conventional plow. Weed control was more difficult after soil was fitted by those methods which mixed the vegetation with the surface soil. Rotary tillage methods were, in general, not satisfactory. Good results were obtained from plots where the soil had been plowed and fitted in one operation. Those methods of tillage left the soil loose, saved a lot of time and resulted in good yields of sugar beets.

The greenhouse experiments reported in this paper showed there is danger in excessively packing soil and the field experiments have shown that maximum beet yields may be obtained on relatively loose soils.

Soil Management Practices for Sugar Beets Grown on Organic Soils

J. F. DAVIS[2]

In 1949 the estimated acreage of sugar beets grown on muck[3] soils in Michigan totaled 7,650 acres[4], representing approximately ten per cent of the total beet acreage. It has been demonstrated repeatedly that high yields of beets can be produced on muck soils with average yields generally higher than those obtained on mineral soils.

The acreage of muck soils in Michigan is estimated at 5,000,000 acres (one acre in eight)[5]. Probably less than two percent of this area is being utilized in the production of cultivated crops at the present time, thus allowing for a considerable expansion of sugar beet production in muck.

A number of factors are associated with the production of high yields of sugar beets on muck soils. Included in this list of factors are soil testing, water control, fertilizer usage, micro-nutrient elements, cultural methods, frost, control of wind damage, the relationship of maturity to sugar content, rotation and variety.

Soil Testing

Sugar beets will grow on muck soils with a wide range in pH. Soil tests for pH should be made on both the surface (0-6 inches) layer and at a twenty-four inch depth. For example, if the subsoil is extremely acid (pH 4.8 or below) the beets become very sprangling and rooty when they reach this acid layer. Generally speaking, when the pH is below 4.8, the addition of lime is advisable, ranging from two to six tons per acre depending on the degree of acidity. It is difficult to get this lime into the lower layers of muck, and the only practical way at present to do this is to spread one-half of the lime on the surface and plow fifteen to eighteen inches deep. Then, apply the other half of the lime after plowing and mix well with the soil by thorough disking. In acid areas burning-off muck is not generally recommended even though the burning will raise the pH of the soil. When muck is burned, there is the loss of the depth of the muck which can further add to the drainage problem.

Water Control

Water control includes both the problem of drainage and also the maintenance of a suitable water level for the crop concerned. The ideal situation is to have water control so that a water table of approximately twenty-four inches can be maintained during the early part of the growing season and then lowered to approximately thirty to thirty-six inches during the latter

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[1] Contribution from the Soil Science Section of the Michigan Agricultural Experiment Station, Michigan State College, East Lansing, Michigan, authorized for publication by the Director as Journal Article No. 1,122.

[2] Associate Professor (Research) of Soil Science.

[3] "Muck" includes all organic soils.

[4] Courtesy of P. A. Reeve, Farmers and Manufacturers Beet Sugar Association, and M. G. Frakes, Michigan Sugar Company.

[5] Muck soils are widely distributed over the state and are found in every county. As much as one-third of the total area in some counties is muck.

Table 1.—The effect of fertilizer ratios on the yield of sugar beets, Michigan State College Muck Experimental Farm, 1949[1]

Fertilizer	Tons per acre[2]
0-20-10	6.7
0-10-10	6.9
0-10-20	10.3
0-10-30	11.4
0-20-0	1.2
No fertilizer	2.3

[1] Fertilizer applied at the rate of 500 pounds per acre. Low yields due to late planting date, June 12. Variety 215x216.
[2] Average of 5 replications except 0-20-0 plot not replicated, unfertilized treatment two replications.

part of the growing season. Factors entering into this problem are the use of dams, pumps, tile, and drainage ditches. Sugar beets should not be grown on poorly-drained muck, since poor drainage is one of the more important causes of low yields of poorly-shaped roots. The maintenance of a relatively high water table early in the growing season acts as a frost preventative measure in that a wet muck is less frosty than a dry surface. Excessive drainage should be avoided.

Table 2.—The effect of fertilizer placement on the yield and stand of sugar beets. Michigan State College Muck Experimental Farm[1]

Treatment		Tons/acre		Plants/200 ft. of row	
0-10-30 Lbs./acre	Placement	1947	1948	1947	1948
200	2" below seed	16.2	19.4	228	205
200	1" to side of and 2" below seed	.....	20.1	.....	201
200	1" to side of and 1½" below seed	16.8	.....	228	.....
300	2" below seed	16.7	21.1	243	227
300	7" drills, 3½" deep	16.7	19.7	221	190
400	7" drills, 3½" deep	.....	19.1	.....	206
400	1" to side of and 2" below seed	.....	20.2	.....	199
400	2" below seed	15.7	18.2	226	202
400	2" to side and 1½" below seed	16.4	.....	230	.....
600	7" drills, 3½" deep	17.5	19.6	234	208

[1] Cooperative experiment with Mr. G. A. Cumings and staff, Division of Farm Machinery, B.P.I.S.A.E., U.S.D.A., and Professor C. M. Hansen, Agricultural Engineering Department, Michigan State College. Data averages of 4 replications.

Fertilization[6]

Fertilization includes the proper selection of the fertilizer grade, placement of this fertilizer and rate of application. The data in Table 1[7] show the need for a ratio high in postash (0-1-3).

Because muck soil is high in nitrogen, unless the soil is just fairly well drained, this element is usually not recommended in the fertilizer mixture. In case that the drainage is not the best for beets, a 3-9-18 fertilizer should be used instead of either the 0-10-20 or the 0-10-30.

[6] The data presented in this report for the years 1946-47-48 were obtained jointly by P. M. Harmer, Professor of Soils, Soil Science Department, Michigan State College, and the author.
[7] For practical purposes a difference of 7 percent between "means" of treatment can be considered as statistically significant.

Placement of fertilizer refers to the position of the fertilizer with respect to the seed. When fertilizer is applied at the rate of 1,000 pounds per acre with a grain drill in seven-inch drills and placed three and one-half inches deep, the time of application either before or after plowing is not important since the average yields over a four-year period regardless of treatment were within one-half ton per acre.

Applying fertilizer broadcast on the surface and disking in thoroughly is not as good a method as applying the same amount of fertilizer with a grain drill, three and one-half inches deep and not disturbing the fertilizer bands, with subsequent cultural treatment before planting. This average increase over a three year period was one ton per acre.

Table 3.—The effect of salt on the yield and percent sucrose of sugar beets. Michigan State College Muck Experimental Farm[1]

Treatment No.	Lbs./acre Salt	1947 Tons/acre	1947 Percent Sucrose	1948 Tons/acre	1948 Percent Sucrose	1949 Tons/acre	1949 Percent Sucrose
1	250 annually	13.3	13.1	19.4	15.1	15.5	16.8
2	500 annually	13.7	14.0	19.6	15.6	15.6	16.3
3	500 every 2 years.	13.8	13.5	19.1	15.1	15.8	16.7
4	1,000 annually	13.1	13.7	18.8	16.1	17.1	16.9
5	1,000 every 2 years.	13.1	15.0	19.9	15.6	16.6	16.4
6	750 annually	12.8	15.1	18.1	16.0	16.5	16.8
7	No salt (K_2O from mine-run potash)	14.1	14.4	19.3	14.8	16.5	16.7
8	No salt (0-10-60)	12.5	12.9	20.4	15.3	16.0	16.5
9	No salt	12.4	13.3	17.5	15.1	15.0	16.7

[1] A uniform application of 1,000 pounds of 0-10-30 applied on all plots with muriate of potash the source of potash except with treatment 7.

The effect of fertilizer placement and rate of application is demonstrated by the results in Table 2. From these data it would appear that neither band placement of the fertilizer nor rate of application affected significantly the yield of beets. However, a question should be raised regarding these data. These experiments were located on land which had received for the past five or six years an annual application of one thousand pounds of fertilizer per acre. Possibly, the residual effect of this fertilizer is responsible for the failure of fertilizer placement and rate of application to influence yields.

Micro-Nutrient Elements

In addition to the regular fertilizer application, four micro-nutrient elements may be needed. These elements are copper, boron, manganese and sodium.

Copper is supplied in the form of copper sulfate and is recommended on mucks with a pH of 6.5 or less. Generally speaking, the more acid the muck, the more likelihood of obtaining a response to the copper application. If the muck is new, an initial application of fifty pounds per acre of copper sulphate is advisable. If beets are to be grown on muck which has had copper applied previously, possibly no further addition of copper will be

Table 4.—The effect of date of planting on the yield and sucrose content of sugar beets. Michigan State College Muck Experimental Farm[1]

1947			1948		
Planting date	Tons/acre (Ave. of 4 replications)	Percent Sucrose	Planting date	Tons/acre (Ave. of 4 replications)	Percent Sucrose
May 6	19.5	14.8	May 17	19.7	16.7
May 16	17.7	15.4	May 25	17.1	16.0
May 26	18.0	14.4	June 3	15.8	16.5
June 4	16.7	15.1	June 12	13.6	16.7
Ave. decrease per day	0.1		Ave. decrease per day	0.24	

[1] A uniform application of 1,000 pounds of 0-10-30 and 500 pounds of salt per acre applied on each plot. Data averages of 4 replications.

required. A rule of the thumb method to follow in determining whether copper would be necessary in this case is—if a total of three-hundred pounds of copper sulfate has been added to the muck prior to planting the sugar beets, then no copper would be needed in the fertilizer. Oftentimes, sugar beets follow crops in the rotation to which copper has been applied previously.

Boron in the form of borax is recommended for beets. Boron deficiency is more likely to occur on an alkaline muck although it may occur on an acid area. Borax should be added to the fertilizer mixture so that twenty-five pounds of borax per acre are applied on an alkaline muck and ten to fifteen pounds per acre on an acid muck.

Manganese is supplied in the form of manganese sulfate for a number of crops. However, this application of manganese sulfate mixed with the fertilizer has not increased yields of sugar beets even though the beets may show manganese deficiency symptoms. Spraying manganese on the foliage may give results. However, very few sugar beet growers have the spraying equipment available for this purpose. Because of the failure of sugar beets to respond to manganese sulfate mixed with the fertilizer, this practice is not recommended.

The use of salt is recommended for sugar beets grown on muck soils. The data in Table 3 show in general that beets respond to salt. However, the seasonal effect should be pointed out. Greater increases in yield from salt applications were obtained in 1948 than in the other two years. The

Table 5.—The effect of maturity on the percent sucrose and apparent purity of sugar beets. Michigan State College Muck Experimental Farm, 1949[1] [2]

Date	Percent Sucrose	Apparent Purity	Mean Weekly Temperatures		
			Maximum	Minimum	Average
Sept. 6	9.8	80.1	77	49	63
12	11.5	90.4	69	46	57.5
19	10.6	82.2	70	44	57
27	11.9	77.6	65	43	54
Oct. 3	13.5	82.4	71	40	55.5
10	13.8	83.1	73	54	63.5
17	14.0	85.6	68	39	53.5
24	15.4	88.4	67	41	54

[1] Variety 215x216—Planted May 16—Harvested October 28.
[2] Samples analyzed through the courtesy of M. J. Buschlen, Michigan Sugar Company, Lansing, Michigan. Plot yield 18.3 tons per acre at time of harvest. Frost occurred on Sept. 9 and 29; Oct. 1, 13, 15, 16, 19 and 23.

results reported in this table agree very closely with those obtained in 1942 when the experiment was begun. However, all mucks do not respond in the same degree to salt applications. Salt apparently had no significant effect on the percent of sugar in the beets.

Cultural Factors

A good seed bed is essential so that an even stand of beets may be obtained. If the muck is of a loose nature and is newly broken, possibly a heavy roller (six hundred to seven hundred pounds per running foot) will aid in maintaining better moisture relations by compacting the muck. This roller should not be used on mucks which have been under cultivation for a few years.

Table 6.—Results of sugar beet variety trials. Michigan State College Muck Experimental Farm[1]

Variety	1947			1948	
	Tons	Percent Sucrose	Apparent Purity	Tons	Percent Sucrose
H15	12.5	11.9	80.4		
H18	14.0	11.5	80.0		
H27	11.3	11.8	78.1		
H29	13.3	12.0	80.8		
H69	11.8	12.1	80.8		
215 x 216	12.9	11.1	78.8	20.1	14.4
Muck	12.7	14.4	81.5	16.9	17.3
H125	----	----		22.0	14.3

[1] 1,000 pounds 0-10-30 and 500 pounds salt applied per acre on all plots in 1947 and 400 pounds 0-10-30 (2" below seed) and 500 pounds salt applied per acre on all plots in 1948. Averages of 3 replications in 1947 and 4 replications in 1948. Cooperative trials with Professor H. Kohls, Farm Crops Department, Michigan State College.

One of the most important factors is early planting. A good illustration of the effect of date of planting can be found in Table 4. In 1947, for each day's delay in planting, one-tenth ton fewer beets were produced. In 1948 this average daily tonnage differential amounted to .24 tons. While no apparent effect on sugar content was noted during these two years, in 1946 the sugar content followed very closely the yield changes. Higher sugar content of beets was obtained from the early planting. It is a good practice to plant the beets early and, if frost appears, to replant immediately. The chance of securing higher yields is well worth the chance of having to replant. A recommended range in planting dates for Michigan conditions is between May 5th and May 25th.

A twenty-eight inch row spacing with beets spaced nine to ten inches in the row is recommended. It might be possible to get higher yields with a narrower row spacing but usually the grower does not have his cultivation equipment set for narrow row spacing.

Observations made at the Michigan State College muck experimental farm in 1949 indicate that either the processed seed or the pelleted seed was equal in producing a stand of beets as the whole seed.

One of the big factors in the successful production of sugar beets is weed control. Unfortunately, cultivation of beets during the early part of the growing period may increase the frost hazard. The question arises then

as to whether one should take a chance and cultivate and thus increase the danger of frost injury.

The necessity of wind control measures has been demonstrated many times by the loss of plantings of sugar beets grown on muck. Inter-plantings of either spring rye or barley between every two or three rows of sugar beets may aid in the prevention of damage to stand through wind action. It is also desirable for a muck farmer to consider the use of windbreaks either of willow or possibly Austrian, Scots or White pines. If inter-plantings of small grain are used, care should be taken not to let this grain get too high before cultivating because of the increased amount of labor which would be required to remove the tall grain plants.

Table 7.—Results of sugar beet variety trials. Michigan State College Muck Experimental Farm, 1949[1]

Variety	Leaf Spot	Tons/acre	Percent Sucrose	Apparent Purity
225X226	Trace	14.0	14.5	81.7
471803-00	Trace	16.5	13.4	78.5
471802-00	Trace	14.6	14.1	19.2
H125	Medium	15.9	13.9	79.9
Muck	Very severe	12.5	17.0	86.4
488-00	Slight	15.5	15.3	87.3
U. S. 226	Slight	15.4	13.1	76.4
486-0	Severe	15.7	14.5	78.7

[1] 500 pounds 0-10-30 and 500 pounds salt per acre applied on all plots. Planted May 17. Severe frost injury occurred June 8. Cooperative variety trial with P. A. Reeve, Agricultural Supervisor, Farmers and Manufacturers Beet Sugar Association.

Maturity in Relation to Sugar Content

The data in Table 5 indicate that the percentage of sugar and apparent purity increase as the crop matures during the fall. These data would indicate that a good sugar content of beets can be obtained when grown on muck soils and that this content increases as the fall season progresses.

Variety

The ideal sugar beet variety would be high in sugar, high yielding, resistant to black root and to leaf-spot, well shaped, early maturing, frost resistant and produce a good type root. Obviously, no variety today has all of these characteristics. The data in Tables 6 and 7 summarize the results of our cooperative trials with sugar beet varieties for the past three years. One of the outstanding results in the performance of the various varieties is the high sugar content of the "Muck" beet, a selection of a Polish variety. However, this variety is very susceptible to leaf-spot. It is hoped that this variety might be used as a parent in producing a variety with high sugar and resistance to leaf-spot.

Labor and Harvesting

In the production of sugar beets on any type of soil, hand labor is required. If sugar beets are included in the rotation more efficient utilization of labor required in mint and onion production can result by providing additional hours of work on the farm during periods in which labor requirements for these crops are small. Attention should be called to the advisability of close supervision of the labor during blocking and subsequent

hoeing operations. Beet fields should not be allowed to become excessively weedy before blocking and thinning. This condition can result in loss of otherwise profitable fields.

Fortunately beets grown on muck soils can be harvested successfully by mechanical means. This factor further demonstrates the adaptability of sugar beets for muck soil production.

Rotation

Sugar beets fit well into the rotation in both special crop and general crop types of muck farming. The best place for the crop in a particular rotation is now under investigation with replicated trials at the Michigan

Table 8.—General cultural recommendations for sugar beets on muck.

Spacing:	28" rows—9-10" between plants in the row
Planting Date:	May 5—May 25
Water table:	30-36 inches
Rate of seeding:	10-15 pounds of whole seed or equivalent amounts of either processed or pelleted seed.
Fertilizer Recommendations:	On well drained muck, 400 to 700 pounds per acre of 0-10-30. Apply in 7" drills, 3½" deep. If equipment is available to place the fertilizer in a band, 400-600 pounds 2-3 inches below the seed or 1" to the side and 2" below the seed. Do not apply more than 150 pounds of fertilizer per acre in contact with seed. If the muck is only fairly well drained, use a 3-9-18 mixture.
	—500 to 1,000 pounds of salt annually —10 to 15 pounds of borax per acre on acid mucks and 25 pounds on alkaline mucks —25 to 50 pounds of copper sulfate per acre on acid mucks until a total of 300 pounds per acre has been used —lime—required only with a pH below 4.8; 2-6 tons per acre depending on the acidity and position of the acid layers.

State College muck experimental farm. Data obtained in 1949 showed that beets following potatoes yielded one ton per acre more than when beets followed mint. Possibly this difference could be ascribed to the poorer stand on the plots following mint. These data should not be considered conclusive since only one year's results are available. Likewise in 1949 no significant differences in yields of beets were obtained on plots following either potatoes or onions.

Summary

1. The production of sugar beets on muck soils offers the possibility of profitably increasing substantially the beet acreage in the state of Michigan.

2. A fertilizer high in potash is required for good yields of beets.

3. Micro-nutrient elements are sometimes necessary. Copper, boron and sodium are recommended based on the pH of the soil and previous fertilizer history of the field.

4. Beets should be planted early on muck and for each day's delay in

planting a reduction of as much as one-quarter ton in yield may result.

5. Close spacing is associated with high yields. With a twenty-eight inch row spacing, the beets should be blocked from nine to ten inches in the row.

6. Inter-plantings of small grains and windbreaks aid in reducing losses from wind damage.

7. It is hoped that the plant breeder will produce a variety better adapted to muck soils than those now available.

Simulated Hail Damage to Sugar Beets 1948-49[1]

H. E. MORRIS

The object of this investigation, begun in 1946 at the Huntley Branch station, Huntley, Montana, was to determine the effect of simulated hail damage on sugar beets. The results of this study for 1946-1947 were published in the Proceeding of American Association of Sugar Beet Technologists for 1948. This report includes the 1948-1949 results, and summarizes the data for the four years.

Table 1.—Simulated Hail Damage 1948

	Fertilized Land			
	Nitrogen added		No Nitrogen added	
Injury	Yield Tons	*Increase or Decrease Tons	Yield Tons	Increase or Decrease Tons
	Defoliated 6-29-48			
0	16.1	———	16.1	———
25	15.7	—0.4	16.2	+0.1
50	14.3	—1.8	14.7	—1.4
100	10.9	—5.2	11.4	—4.7
	Defoliated 7-28-48			
0	16.2	———	15.4	———
25	13.3	—2.8	15.6	+0.2
50	15.8	—0.4	14.5	—0.9
100	9.5	—6.7	7.7	—7.7
	Defoliated 8-25-48			
0	16.7	———	16.7	———
25	15.8	—0.9	14.2	—2.5
50	15.2	—1.5	14.2	—2.5
100	14.7	—2.0	12.0	—4.7

*In relation to the check.

In conducting this work the simulated hail injury to sugar beets was produced three times each year on the triplicate plots at approximately monthly intervals beginning June 26. On each date 100, 50, 25, and 0 per cent of the leaf area of the beet was destroyed. A plot consisted of four rows of beets, 26.2 feet long, of which the two center rows equal to one-five hundredth of an acre were harvested. The injury was produced by whipping the plants with a flexible wooden whip.

Fertilized land, which received an application of 16 loads of manure and 200 pounds of treble superphosphate per acre the previous fall, and unfertilized land were used. On one series on both fertilized and unfertilized land, an application of nitrogen (150 pounds of ammonium sulphate and 150 pounds of sodium nitrate per acre) was made on each date following

[1] Contribution from Montana State College, Botany and Bacteriology Department, Agricultural Experiment Station. Paper No. 233 Journal Series.

the injury. The land was fall-plowed and in the spring and summer received the recommended cultural practices, similar to those used on the other beet acreage at the Station. In 1948 and 1949 a mixture of U. S. 22 and G. W. 268 sugar beet seed was planted at the rate of 4 pounds per acre. The beets were planted April 22, and harvested September 30 (150 days after planting) each year.

The loss of yield on the fertilized land for the 100, 50, and 25 per cent defoliation on June 29, July 28, and August 29, 1948 is shown in Table 1.

The nitrogen application in June was not very effective, in July there was a slight effect, and the August application showed the most pronounced effect.

Table 2.—Simulated Hail Damage 1948

	Unfertilized land			
	Nitrogen added		No Nitrogen added	
Injury	Yield Tons	*Increase or Decrease Tons	Yield Tons	Increase or Decrease Tons
		Defoliated 6-24-48		
0	13.5	.....	13.5	.....
25	13.7	+0.2	13.5	.....
50	13.3	—0.2	12.0	—1.5
100	10.1	—3.4	8.4	—5.1
		Defoliated 7-26-48		
0	12.0	.....	13.4	.....
25	10.0	—2.0	10.3	—3.1
50	11.4	—0.6	8.7	—4.7
100	5.0	—7.0	5.5	—7.9
		Defoliated 8-25-48		
0	16.6	.....	17.9	.....
25	16.5	—0.1	16.1	—1.8
50	14.1	—2.5	14.6	—3.3
100	11.8	—4.8	12.8	—5.1

*In relation to the Check.

The loss of yield on the unfertilized land for the 100, 50, and 25 per cent defoliation on June 29, July 28, and August 29, 1948, is shown in Table 2.

Nitrogen applied after injury in June, July, and August showed a beneficial effect in practically all cases on the unfertilized land.

The results of the simulated hail injury experiments in 1949 were erratic, due to an epidemic of rhizoctonia root rot which proved serious. The method of procedure was identical to that described for 1948. The 100 per cent defoliation on June 24, July 31, and August 26, 1949, resulted in a loss of yield as indicated in Table 3. The 50 and 25 per cent defoliation was erratic, sometimes the 25 per cent injury resulting in more damage than the 50 and vice-versa. The presence of the disease materially reduced the stand, and the beets which survived grew larger due to an enlarged feeding area. Since the tonnage-yield is calculated on weight per harvested beet times stand, errors probably resulted in the interpretation of the yield per acre.

The experiment will be continued in 1950 on land which has not been planted to beets for several years.

Table 3.—Simulated Hail Injury 1949

	Fertilized Land				Unfertilized Land			
	Nitrogen Added		No Nitrogen Added		Nitrogen Added		No Nitrogen Added	
Injury	Yield Tons	*Increase or Decrease Tons	Yield Tons	Increase or Decrease Tons	Yield Tons	Increase or Decrease Tons	Yield Tons	Increase or Decrease Tons
				Defoliated June 24				
0	18.2	.....	18.2	.....	17.2	.....	13.3	.....
100	13.4	—4.8	13.6	—4.6	13.9	—3.3	10.9	—2.4
				Defoliated July 31				
0	14.9	.....	15.8	.....	16.7	.....	12.9	.....
100	10.6	—4.3	13.4	—2.4	9.4	—7.3	8.6	—4.3
				Defoliated Aug. 26				
0	13.8	.....	15.9	.....	13.2	.....	13.5	.....
100	12.8	—1.0	9.6	—6.0	11.3	—1.9	11.8	—1.7

*In Relation to the Check.

Summary

The results of this study for four years, 1946-1949 inclusive, show that complete defoliation (100 per cent) or partial defoliation (50 per cent) during the latter part of June or July causes an average loss of approximately one-fourth of the crop for complete defoliation (100 per cent) and one-sixth for partial defoliation (50 per cent).

The 25 per cent defoliation usually causes a loss of less than 10 per cent, and in some cases no loss.

Complete defoliation (100 per cent) in August causes less loss of tonnage but decreases the sugar content of the beet 2-4 per cent. Partial defoliation (50 and 25 per cent) causes little loss in tonnage or percentage of sugar.

In general, an application of a nitrogen fertilization was beneficial. It apparently aided in a more rapid recovery of the beets.

Irrigation and Soil Fertility

A Study of the Effects of Some Different Sods and Fertilizers On Sugar Beet Yields[1]

C. M. GREGG AND C. M. HARRISON[2]

Differences oberved in growth behavior of sugar beets when planted on a field previously laid out in a pasture experiment led to the present experiment. The pasture plots were a twenty-fourth of an acre in size, and included eight replications of eleven different forage mixtures. It was possible to restake the original pasture plots by observable differences in the growth of the beets during their first two months of growth. In an attempt to see whether these observable differences could be measured and interpreted, the following experiment was set up.

The plots used in this test were seeded to grass and grass-legume mixtures in 1943.[3] The test plots were on a soil described as Conover light silt loam. There were sixteen different types of sods of which only ten will be considered in this paper. Sugar beets were grown on these plots two years in succession in order to better observe persistency of the effects of the different sods on the sugar beets. At harvest the beets were counted, weighed, and sucrose tests run on a representative sample from each plot. In 1948, physical measurements were made on beets in a section of each plot.

During the growing season observations were made as to the appearance of the beets. Penetrometer tests were made periodically through the growing season in 1949. Organic matter determinations were made on soil samples taken just before the land was plowed in both 1948 and 1949. Aggregation and clay analysis as well as pH tests were made on soil samples from these plots. Porosity determinations were made in 1949.

The beets from bromegrass, brome-alfalfa, orchard grass-alfalfa, and plots of both bluegrass sods showed better than average growth appearance, while beets on the timothy-red clover and both fescue plots were below average in their growth.

The rainfall was about 50 percent of normal during July and August in 1948, therefore the yields from all plots were rather low. The rainfall for the same two months in 1949 was about normal, consequently the average yield from all plots, combined, was about as high as in 1948 in spite of a decrease in average stand from 74 to 49 percent.

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[1] Contribution from the Section of Farm Crops, Michigan Agricultural Experiment Station, East Lansing, Michigan, Journal Article No. 1140. Part of a thesis submitted by the senior author at Michigan State College in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

[2] Graduate assistant and professor, respectively, Farm Crops Department, Michigan State College. This research was supported in part by a grant from the Farmers and Manufacturers Beet Sugar Association of Michigan.

[3] Morrish, R. H., and Harrison, C. M. The Establishment and Comparative Wear Resistance of Various Grasses and Grass Legume Mixtures to Vehicular Traffic. Journal American Society of Agronomy, Vol. 40, No. 2, pp. 168-179, 1948.

The plots of beets following orchard grass, orchard-alfalfa bromegrass and brome-alfalfa sods gave highest average yields per acre both years, in spite of the fact that the beets on redtop and Canada bluegrass sods had higher percent stands in 1948 than any of the grasses except orchard grass.

TABLE 1. Average Yields and Stands of Sugar Beets of Different Sods

Sod plots	Average % Stand		Average Yield Tons/A.		Yield of Sugar Lbs./A.	
	1948	1949	1948	1949	1948	1949
Brome-Alfalfa	70.7	58.0	7.99	8.99	2,314	2,712
Timothy-Red Clover	56.6	31.4	4.88	3.80	1,316	1,133
Bromegrass	73.8	54.6	8.09	9.12	2,300	2,858
Kentucky Bluegrass	68.1	30.5	7.20	4.56	2,050	1,368
Chewings Fescue	70.0	45.6	5.95	5.97	1,758	1,799
Sheep Fescue	63.3	27.9	4.25	3.31	1,169	1,008
Redtop	81.6	38.9	7.78	5.07	2,355	1,512
Canada Bluegrass	81.9	44.0	7.17	6.17	2,129	1,957
Orchard-Alfalfa	79.1	77.9	9.33	9.81	2,682	2,617
Orchard grass	91.0	78.3	8.85	13.15	2,687	4,123

In 1949 the percent stands on these better yielding plots were much higher than on any of the other sods. Likewise, yields of sugar beets for both years averaged lowest following timothy-red clover and sheep fescue sods. Beets following sods of redtop and the two bluegrasses were very near the average in yields for all treatments in 1948, but the average from chewings fescue sod plots was below average. In 1949 beet yields following Kentucky bluegrass and redtop sod dropped below that of the chewings fescue, which produced approximately the same yield per acre as in 1948. Yields of beets on Canada bluegrass, sheep fescue and timothy-red clover sods were lower in

TABLE 2. Weights per beet, percent sucrose and coefficients of apparent purity

Sod Plots	Wt. Per Beet Average		Average % Sucrose		Average Coefficient of Apparent Purity (%)	
	1948	1949	1948	1949	1948	1949
Brome-Alfalfa	1.20	1.65	16.1	16.7	86.75	86.85
Timothy-Red Clover	0.92	1.29	15.6	16.5	86.58	87.62
Bromegrass	1.17	1.78	16.8	16.8	85.80	88.68
Kentucky Bluegrass	1.11	1.56	16.2	16.2	86.44	88.56
Chewings Fescue	0.89	1.35	16.8	16.8	87.18	88.03
Sheep Fescue	0.70	1.25	15.6	16.9	86.52	89.11
Redtop	1.02	1.39	17.2	16.6	88.20	87.13
Canada Bluegrass	0.87	1.48	17.2	17.3	86.13	88.66
Orchard-Alfalfa	1.26	1.34	17.1	15.1	85.04	88.25
Orchard grass	1.04	1.60	17.4	17.2	87.90	90.79

1949 than in 1948. On the other hand, the beets following those sods which gave best yields in 1948 resulted in increased yields in 1949. Due to a high percent of sucrose and a high coefficient of apparent purity the beets following redtop produced a high average yield of pure sugar per acre in 1948. However, this condition did not prevail in 1949.

As shown in Table 2, beets from the sod plots of brome-alfalfa, bromegrass, orchard grass, orchard-alfalfa and Kentucky Bluegrass were heavier

than the average weight of beets from all plots in 1948. Beets of average weight were produced on the redtop sod plots while the other sods produced beets smaller than the average, with those from sheep fescue sod

TABLE 3. Summary of Soil Analysis Studies

		%	Organic Matter[1] %		Pore Space % Volume		Aggregates[2] % Water
			1948	1949	Total	Non-cap.	Stable
Brome-Alfalfa	7.54	15.0	2.80	3.05	55.4	20.3	82.4
Timothy-Red Clover	6.31	19.0	3.50	2.20	52.2	19.3	80.0
Bromegrass	6.74	18.2	3.20	1.82	53.3	16.2	74.3
Kentucky Bluegrass	6.41	21.3	4.35	2.88	55.4	17.1	77.9
Chewings Fescue	7.00	17.8	3.25	2.65	54.2	19.9	72.0
Sheep Fescue	6.61	19.0	3.80	2.87	50.9	15.8	76.1
Redtop	6.54	15.0	2.38	3.08	53.0	17.7	67.3
Canada Bluegrass	6.64	14.2	1.51	3.20	49.8	13.3	57.9
Orchard-Alfalfa	7.38	14.0	2.26	1.96	55.8	19.9	74.1
Orchard grass	7.82	13.5	2.00	1.75	56.0	20.4	63.5

[1] Graham, E. R. Determination of Soil Organic Matter by Means of a Photoelectric Colorimeter. Soil Science, Vol. 65, pp. 181-184, 1948.
[2] Particles less than 0.1 mm. remaining in aggregates determined by the Yoder method.

averaging smallest of all. In 1949 there was little change in the order of rank in size of beets, though all averaged larger than in 1948. The beets from the orchard-alfalfa plot averaged a little less, while those from Canada bluegrass plots were slightly above the average for beets from all the plots,

TABLE 4. Penetrometer Tests for Compaction Studies on Plots[1]
Pressure required to press penetrometer to six inch depth

Sod plots	Pounds pressure at different test dates			
	May 24	July 2	July 16	July 22
Brome-Alfalfa	37.0	31.0	38.3	74.0
Timothy-Red Clover	26.6	38.0	45.2	66.7
Bromegrass	29.6	33.5	37.2	72.9
Kentucky Bluegrass	28.9	33.7	42.7	54.7
Chewings Fescue	29.6	38.0	44.2	52.7
Sheep Fescue	27.1	32.5	47.7	67.3
Redtop	31.9	33.8	43.5	64.3
Canada Bluegrass	26.9	37.8	46.8	68.7
Orchard-Alfalfa	35.7	42.8	37.2	81.7
Orchard grass	37.2	42.0	41.0	78.0
Averages	31.0	36.3	42.4	68.1

[1] Determinations made with a penetrometer which was so constructed that it plotted pressure in pounds against inches in depth.

and beets from the sheep fescue and timothy-red clover plots still averaged smallest of all the plots. There was little difference in the coefficient of apparent purity among the different sod treatments, though it averaged a little higher in 1949.

There was a positive correlation at the five percent level between the pH of the soil, as shown in Table 3, and the yield in tons of sugar beets per acre on the plots. There was a positive correlation between pH and the percent stand of beets at harvest time in the 1949 crop.

Percent clay showed a significant negative relation to percent of stand of beets at the one percent level in 1947, but the relation was at the two percent level in 1949. In both years percent of clay had a negative correlation to yield at the five percent level. Percent of organic matter showed no significant relation to yield of sugar beets on these plots. There was no correlation between percent of aggregation and stand or yield of beets in these plots. Neither total pore space nor non-capillary pore space showed any correlation to yield in these tests.

In the compaction studies on these plots the first tests were made May 24, but due to excessive rainfall there were no tests made in June. Tests were made through the month of July and a final test was made August 15. Some of the results of the penetrometer tests are given in Table 4.

TABLE 5. Fertilizer Studies

Fertilizer Used Kind	Amounts Used on Plots (Per Acre) A	B	C	D	E	F
20-0-0	120	240	.....	480	480	.....
3-12-12	396	792	.....	.....	1,584	2,028
Yield in Tons of Beets Per Acre						
1948	6.92	7.47	5.59	6.19	8.04	8.70
1949	7.03	7.23	3.85	4.58	8.19	11.24
Percent Stand of Beets						
1948	78.2	75.7	71.9	57.5	71.9	79.7
1949	44.0	46.5	31.1	31.6	52.4	67.8

These determinations showed that the bromegrass, brome-alfalfa, orchard grass, and orchard-alfalfa sod plots, though relatively firm at first, were less compact than all the others July 16, and required less than average pressure to penetrate to a six-inch depth. The tests on July 22 showed a reversal in that the soils of these four treatments which had remained mellow to July 16 had become more compact than any of the other plots, requiring considerably more than the average pressure to penetrate to the six-inch depth. The tests August 15 were made just three days after a rainfall of 1.15 inches and there was little change except that all plots were less compact than at the July 22 test.

All of the sod plots were cross-checked with five different fertilizer treatments and a check strip receiving no fertilizer as shown in Table 5.

In 1948 there was very little benefit in yield from use of heavier applications of fertilizer. The yields from all the plots were low, evidently due to the very low rainfall in July and August. Only strip A produced enough above the unfertilized check C to pay for the fertilizer used in 1948. The percent of stand of beets on strip D which received only nitrogen fertilizer was very low compared to the other treatments.

Results for 1949 varied much more widely between treatments, both in percent stand at harvest time and yield in tons of beets per acre. Again treatment D was at the bottom in percent stand but this time strip C, the check, was equally as low. In 1949 only strip D failed to increase the yield above that of the unfertilized check enough to pay for the fertilizer used.

In the other treatments percents of stand and yield were increased when the amount of 3-12-12 fertilizer was increased. The beets on the plots receiving heavier applications of 3-12-12 fertilizer emerged more quickly and grew more vigorously than those receiving the smaller amounts or none of this fertilizer.

Summary

1. A difference was found in the yield of sugar beets following the different grass sods studied.

2. Of the sods tested orchard grass and bromegrass, with or without alfalfa, gave best percentages of stand of beets and yield in tons per acre. The fescues and timothy gave poorest results, while the bluegrass and redtop were intermediate.

3. This study indicated that increased amounts of 3-12-12 fertilizer resulted in higher percent stands of beets than those receiving only nitrogen fertilizer.

4. There was a close correlation between the yields of sugar beets on these plots and the root growth habits of the grasses which had grown in the sods.

5. Observations indicated that a soil should remain mellow for at least the first half of the growing season for best growth and production of sugar beets and that, of the grasses used in this study, orchard grass and bromegrass promoted this condition best.

6. There was no correlation between the aggregation or the pore space of the soil and the yield of sugar beets.

7. There was a significant negative correlation of clay content of the soils to percent stand and to yield of sugar beets.

8. Under conditions of this study the addition of nitrogen fertilizer was not profitable.

Levels of Available Phosphate in Soils in Utah, Idaho, Washington, Montana and South Dakota as Shown by Soil Tests

BION TOLMAN AND R. S. GADDIE[1]

INTRODUCTION

During the past five years the Utah-Idaho Sugar Company, in cooperation with farmers throughout the area in which it operates, has conducted more than 350 field trials with commercial fertilizers. These trials were designed so as to determine the deficiency of both phosphorus and nitrogen.

Phosphate response in these field trials has varied greatly from one test field to another, and from one area to another. In many cases where phosphate deficiency was indicated it was not possible to determine in the field the degree of deficiency, due to the fact that many other factors at times become limiting or partially limiting factors.

Another disturbing factor in determining phosphate requirements through the use of field trials alone is the fact that it is not practical to conduct a field trial on every farmer's farm. Inasmuch as past cropping history and past fertilizer history makes each farm an individual problem, work was undertaken to check the results of soil analysis with the results of actual field trials, in the hope that the correlation would be close enough to make the use of soil tests a valuable supplement to field trials in making fertilizer recommendations.

The correlation of available phosphate tests and results from field trials was made by determining the available phosphate level on the unfertilized check plots of each field trial and correlating the phosphate level found with the yield increase obtained on plots receiving phosphate applications. After extensive comparisons over a period of two years, it was decided that soil tests could be used to supplement the data obtained from field trials, and an extensive soil sampling and soil analysis program was undertaken. This paper reports the results of soil samples analyzed from Utah, Idaho, Washington, Montana and South Dakota during 1949.

SOIL TESTING PROCEDURES

Obtaining the Soil Sample

All soil samples were taken by members of the Sugar Company field staff. The sample from each field tested was obtained by using a small soil sampling tube which could be pushed into the top 6 to 8 inches of soil. At least 12 small samples were obtained over the field area, and this soil was mixed thoroughly in a bucket. A composite sample of about 1.5 pounds of soil from each field sampled was sent to the local factory chemist to be air dried, sieved, and reduced to 100 grams by use of a Jones sampler. At regular intervals as sufficient samples were accumulated they were sent to the General Laboratory for analysis.

[1] General Agricultural Superintendent and Chief Chemist of Utah-Idaho Sugar Company.

Methods of Analyses

Apparatus, reagents, and procedures followed in making the analysis for available PO_4 are outlined briefly below:

Apparatus

Electrophotometer with 650 filter or set at 650 millimicrons
Dense filter paper (E and D Folded paper No. 193, 15 cm.)
Lipped tumblers or 250 ml. beakers
125 ml. flasks
15 ml. pipettes
Special Burettes
Bulb dropper
500 ml. wide mouth bottles fitted with 2 hole stoppers and connecting tubes
Cylinder of CO_2 with reducing valve
Pulp balance

Reagents

Ammonium molybdate — dissolve 25 gm. of ammonium molybdate in 200 ml. distilled water at 60° C. Cool and filter. Dilute 280 ml. of conc. H_2SO_4 to about 750 ml. and cool. Pour the molybdate solution slowly with stirring into the acid solution. Cool and make up to 1 liter.

Stannous Chloride — Make up a 10% HCl solution by diluting 225 ml. conc. HCl to 1 liter. Dissolve 0.5 gm. of $Sn\ Cl_2\ 2H_2O$ in 20 ml. of the 10% HCl. **This solution must be prepared fresh every day.**

Procedure

Add 250 ml. distilled water to each of not more than 6 wide mouth bottles. Then weigh on the pulp balance 50 gm. of soil into each bottle. Stopper the bottles with the solid stoppers and shake. Insert the train of connecting tubes so arranged that the inlet tubes reach within about ¼ inch of the bottom of each bottle while the outlet tubes extend only slightly through the stoppers. Connect the inlet tube of the end bottle with the CO_2 and bubble a fairly brisk stream of gas through the six suspensions in series. Bubbling should not be so violent as to allow spray from one bottle to be carried into the next bottle by the CO_2. Twirl the bottles several times to allow all the soil to come into contact with the carbonic acid. At the end of a 15-minute bubbling period remove the tubes, replace the solid stoppers in the same bottles they were used for the first shaking and shake. Filter immediately. Discard the first 1 to 20 ml. of filtrate. The filtrate must be perfectly clear. If it is not, refilter.

Pipette duplicate 15 ml. aliquots into 125 ml. flasks. Add 85 ml. distilled water, then add 4.4 ml. of molybdate solution. Balance the photometer using distilled water and 650 millimicron band. To the samples add exactly 10 drops of stannous chloride solution and swirl, allowing time to take a reading between each addition. Obtain the transmittancy exactly 5 minutes after adding the stannous chloride. Balance the instrument on the distilled water between the duplicates.

The amount of available phosphorus as PO_4 was determined from a curve prepared from a series of known standards. A blank determination on two of the standards was run twice each day.

ANALYTICAL RESULTS

Soil samples were taken during August, September and October of 1949 from fields which farmers indicated would go into beets in the spring of 1950. A total of more than 4500 soil samples was analyzed The results of these analyses by factory district are shown in Table 1.

The available phosphate level varied greatly between districts. The phosphate level was highest in the Gunnison district in Utah, followed by the Toppenish factory district in Washington. The two lowest areas were the Chinook factory district in Montana and the Belle Fourche factory district in South Dakota.

Table 1.—Results of more than 4500 Soil Analyses for Available Phosphorus, Showing the Percentage of the Samples Falling into Each of the Available Phosphate Groups. Available Phosphate Level is Expressed in P.P.M.* of PO_4.

District	0-5 P.P.M.	6-10 P.P.M.	11-15 P.P.M.	16-20 P.P.M.	21-25 P.P.M.	Over 25 P.P.M.
Gunnison, Utah	5	19	16	15	11	34
West Jordan, Utah	20	26	16	12	7	9
Garland, Utah	29	32	19	8	5	7
Idaho	22	27	18	10	9	14
Washington	11	22	18	13	10	26
Montana	63	19	6	3	3	6
South Dakota	68	20	6	2	1	3
Nebraska	31	31	27	3	5	3

*P.P.M. is symbol used for parts per million.

Within any one of the districts, available phosphate levels varied from as low as 2 parts per million to in excess of 100 parts per million. This extreme variation provided an opportunity to check the available phosphate levels with the level of crop production and with the record of past fertilizer practice. In every instance, high available phosphate level occurred on farms where farmers were applying phosphate fertilizer to both sugar beets and alfalfa. On the other hand, the extremely low phosphate levels were found on farms where there had been little or no past use of commercial fertilizer carrying phosphate. Low phosphate level was generally associated with areas and farms where the nitrogen level was known to be low, and as a consequence either the low phosphate level or the low nitrogen level, or both, were responsible for low levels of crop production.

In many other cases nitrogen level was low but phosphate level was high. In these cases farmers had been making annual application of treble superphosphate but had ignored the nitrogen supply. In these cases the high phosphate level so aggravated the nitrogen deficiency that additional applications of phosphate fertilizer not only gave no yield response but in many cases actually decreased yields.

In correlating the available phosphate level with field tests, many cases were encountered where phosphate applications alone gave no yield response, even though the soil analysis showed the phosphate level to be

extremely low. In almost every one of these cases nitrogen alone gave a response, and mixed fertilizer which supplied both nitrogen and phosphate produced a yield response which was much greater than that produced by either one of the elements applied alone.

These facts stress the importance of using mixed fertilizer in adequate amounts to supply both the nitrogen and phosphate requirements. Inasmuch as field tests have shown that in a great majority of cases minimum nitrogen requirements range from 45 to 60 pounds of nitrogen per acre, it readily becomes apparent that, if we use such mixed fertilizers as 12-15-0 or 16-20-0 or 15-11-0, then we must use a minimum of 300 to 400 pounds per acre.

The soil test used in conjunction with field trials and past cropping and fertilizer use history makes it possible to recommend more nearly the fertilizer ratio which is needed for maximum crop production.

Use of Available Phosphate Test as a Help In Determining Need of Phosphate

JAMES THORNE AND BION TOLMAN[1]

The need for chemical methods of estimating fertilizer requirements has been recognized for many years. At present there is a special need for a method of evaluating the available supplies of phosphate in soils of the western sugar beet growing areas. This is so because such great extremes in phosphate level exist in these soils.

About twenty-five years ago quite general responses to phosphate were noted in the sugar beet fields. Without soil tests as an index to phosphate levels in the soil, phosphate fertilizers have been used regularly on many of the beet fields since this time. As a result, many soils have accumulated large reserves of available phosphorus. In many cases additional phosphate is not needed and probably will not be needed for several years. On the other extreme are many soils producing poor yields of sugar beets because of insufficient supplies of readily available phosphorus. Some of these fields have also received some phosphate fertilizer but not adequate amounts.

While a number of states in the East and Midwest have, over a period of years, established useful correlations between soil test values and crop responses to fertilizers, investigators in the West, generally, have not accumulated much data in support of soil test values. Attempts to apply chemical procedures and nutrient levels developed in the East to Western conditions have been largely unsuccessful. (2)[2]

New analytical methods and new correlations had to be worked out to fit Western conditions. McGeorge (1) proposed the use of carbonic acid as opposed to organic or buffered inorganic acid solutions for extracting available plant nutrients from calcareous soils. Tests made in Idaho support this carbonic acid method of extraction.

Experimental Procedure

During 1947, 1948 and 1949, data were obtained from a number of representative sugar beet growing areas throughout Utah and Idaho. The carbon-dioxide soluble phosphate was measured on samples of soil from check plots and compared with yield response to phosphate alone and to phosphate in combination with nitrogen. The original purpose of these plot tests was to establish suitable fertilizer amounts and ratios for the different areas. The experiment was not designed specifically for determining the correlation between available phosphorus and crop response. Had this correlation been the major objective some variables could have been eliminated and a much closer relationship most likely would have been found.

[1] Soil Testing Laboratory, Utah State Agricultural College; Utah-Idaho Sugar Co.
[2] Numbers in parentheses refer to literature cited.

Results

It was immediately evident that beets grown on soils with very low available phosphate contents (0-5 ppm as PO_4) responded to phosphate fertilizer with but very few exceptions. On the other hand beets on soils containing high amounts of phosphate (>50 ppm) very seldom gave any increase in yield due to applied phosphate even when in combination with nitrogen. Available phosphorus contents in between these two extremes were somewhat less closely related to yield responses.

The data are summarized as follows (Table 1), assuming that 20 ppm of available PO_4 is a critical level.

Table 1.

	Available PO_4 less than 20 parts per million Percent	Available PO_4 greater than 20 parts per million Percent
Percentage of tests responding to phosphate applications	72	32
Percentage of tests showing no response to phosphate applications	18	68
Percentage of tests showing response to nitrogen applied alone	80	91
Percentage of tests showing greater response to mixture of N + P than to nitrogen alone	84	36
Percentage of tests where it would have been most profitable to apply nitrogen alone	16	64

Thus the chances for predicting the phosphate need from the analysis of any given sample depend somewhat upon what the available amount is. If the amount is very low or very high, a fairly accurate prediction can be made. Chances are 3 to 1 that yield increases of sugar beets will be obtained if the soil contains less than 20 ppm of CO_2 soluble PO_4.

Recommendations for the use of phosphate fertilizer must, of course, be made in view of other factors which influence yield; but the soil test value is a fairly reliable index to the phosphate-supplying power of a soil.

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Utilization of Phosphorus From Various Fertilizer Materials By Sugar Beets in Colorado[1]

STERLING R. OLSEN, ROBERT GARDNER, W. R. SCHMEHL, FRANK S. WATANABE, AND C. O. SCOTT

Many questions remain unanswered regarding the relative availability of various phosphate fertilizers on calcareous soils. Results on acid soils are not necessarily applicable to the irrigated soils of the West. Although a number of experiments comparing source of phosphorus have been conducted on calcareous soils, the results obtained vary with location and are neither conclusive nor unanimous on the relative availability of the various fertilizers (3, 6, 9, 11, 12)[2]. The introduction of the radioactive tracer technique to field experimentation with phosphate fertilizers provides a more accurate method for comparing the availability of various fertilizer materials (1, 10, 13). In a single season, the radioactive method supplies considerably more information on the availability of the fertilizer than can be obtained by the usual yield measurements.

The effect of source of phosphorus, placement, rate, and time of application on the utilization of phosphorus by sugar beets and its movement in the soil are reported in this paper. A more comprehensive report including other crops may be found elsewhere (8).

MATERIALS AND METHODS

The radioactive fertilizers used in 1948 are described by Hill, et al. (2), and those used in 1949 were prepared in a similar manner[3]. These were applied with a four-row belt-type distributor mounted on a tractor specially designed for using radioactive materials. The activity of the fertilizers at the time of application was about 0.1 millcurie per gram of P_2O_5.

Plant assays[4] for P^{32} and P^{31} were made according to described procedures (4, 5).

Detailed descriptions of the two experiments conducted in 1948 were presented previously (7).

Three new materials were added in the 1949 experiments: ammonium phosphate (11-48-0), treble superphosphate, and liquid phosphoric acid. Both 1949 experiments were conducted on the Fort Collins loam (Agronomy Farm) described previously (7). Four materials were included in one ex-

[1] Report of a study made under the Research and Marketing Act of 1946. Joint contribution: Colorado A & M Agricultural Experiment Station and the Bureau of Plant Industry, Soils and Agricultural Engineering, USDA. This work was supported in part by grants from the Industry Phosphate Research committee, the Tennessee Valley Authority, and the Anaconda Copper Mining Company. Authorized by the Director of the Colorado A & M Agricultural Experiment Station for publication as Scientific Journal Series Article No. 327.

[2] Numbers in parentheses refer to literature cited.

[3] The preparation and distribution of the fertilizer materials containing P^{32} was accomplished by W. L. Hill, E. J. Fox, S. B. Hendricks, and L. A. Dean at the Plant Industry Station, Beltsville, Md. All radioactive phosphorus was supplied by the Atomic Energy Commission.

[4] Assays for P^{31} and P^{32} in 1948 were made in the laboratories of the North Carolina Agricultural Experiment Station under the supervision of N. S. Hall and A. J. MacKenzie.

periment. The materials were ammonium phosphate, superphosphate (20%), calcium metaphosphate, and alpha tricalcium phosphate. All were tested at two placements; and one, the superphosphate, at two rates. The placements were (a) phosphorus mixed with a rototiller in a band 4 inches wide and 4 inches deep, and (b) phosphorus placed in a single band 4 inches deep and 4 inches to one side of the row (the same as in 1948). Phosphorus was applied at the rate of 40 pounds of P_2O_5 per acre and nitrogen at 80 pounds N per acre. One superphosphate plot per replication received 80 pounds of P_2O_5 per acre. There were three replications for each placement. Each plot was 8 rows wide and 64 feet long. Three rows 32 feet long received radioactive fertilizer. These plots were irrigated July 5, August 5 and August 31.

Another experiment was conducted to compare treble superphosphate applied at planting time and on June 29 with liquid phosphoric acid applied June 29. Phosphorus was applied at the rate of 80 pounds of P_2O_5 per acre and nitrogen at 80 pounds N per acre. The dry fertilizer was placed in a band 4 inches deep and 4 inches to one side of the row at planting time and 4 to 5 inches deep and 6 inches to one side of the row on June 29.

The liquid phosphoric acid was applied in the irrigation water as follows: The acid was mixed with water in 10-gallon milk cans placed on a truck and applied to the furrow through a faucet and garden hose to 8-foot sections of the row. The water was applied at the rate of one inch per acre. The cans were filled with water by a hose from the municipal water supply. All plots received a normal irrigation the following day. Two rows 32 feet long received radioactive phosphate (3 furrows in the case of H_3PO_4), while the remaining rows received ordinary phosphate at the same rate. The radiophosphorus was added to each can as a solution of radioactive KH_2PO_4. There were 8 rows per plot 64 feet long and 6 replications. These plots were irrigated on June 30, July 28, and August 24.

Dates of field operations are shown in Table 1.

Table 1.—Dates of field operations.

Locations	Date of Planting	Sampling Date[1] 1	2	3	4	5
		Sugar beets (dry fertilizer)				
Agronomy Farm, 1948	April 24	May 28	June 24	Aug. 2	Sept. 13	.....
Agronomy Farm, 1949	April 22	June 10	July 1	Aug. 10	Sept. 8	.....
Hoffman Farm, 1948	April 27	May 29	June 30	Aug. 10	Sept. 14	.....
		Sugar beets (liquid vs. dry)				
Agronomy Farm, 1949	May 2	July 7	Aug. 1	Aug. 22	Sept. 14	Oct. 10

[1] The sampling dates correspond to the following stages of growth:
Sugar beets (dry fertilizer):
1. Thinning time.
2. Beginning of grand period of growth.
3. Middle of grand period of growth.
4. Near harvest time.

Sugar beets (liquid vs. dry):
1. One week after liquid H_3PO_4 was applied.
2, 3, 4. Intermediate stages.
5. Harvest time.

MOVEMENT OF APPLIED PHOSPHORUS

The movement of the radiophosphorus in the fertilizer can be followed readily by measuring the activity of the soil itself. Successive samples were taken July 23 from the bottom of the irrigation furrow to a depth of 18 inches on the sugar beet plots receiving liquid phosphoric acid.

Liquid phosphoric acid containing radiophosphorus was also applied at 80 pounds P_2O_5 per acre to fallow land in 8-foot sections of furrows similar

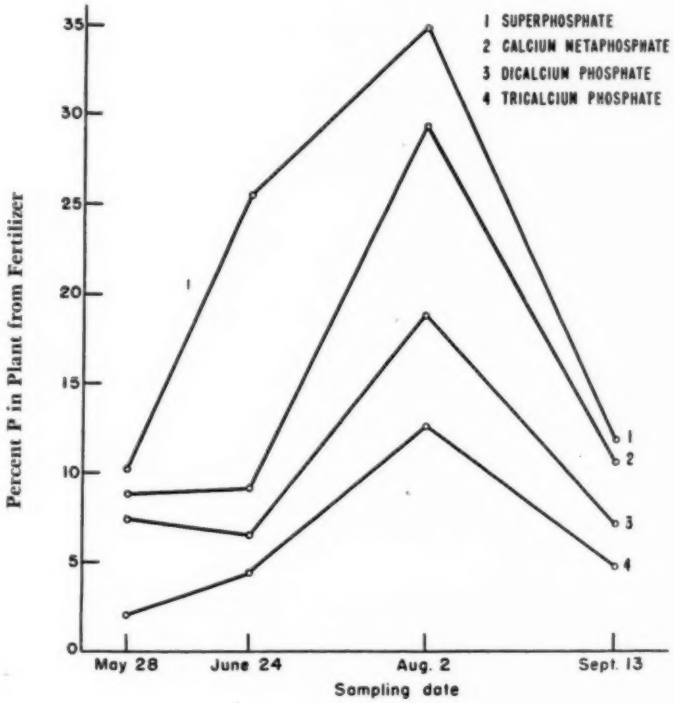


Figure 1. Percentage of Phosphorus Derived from Fertilizer as Affected by Source of Phosphorus on Fort Collins Loam (1948).

to those used on sugar beets. The fertilizer was mixed with a volume of water equal to irrigation rates of one-third, one, and three inches of water per acre to determine the effect of dilution on movement. This was followed

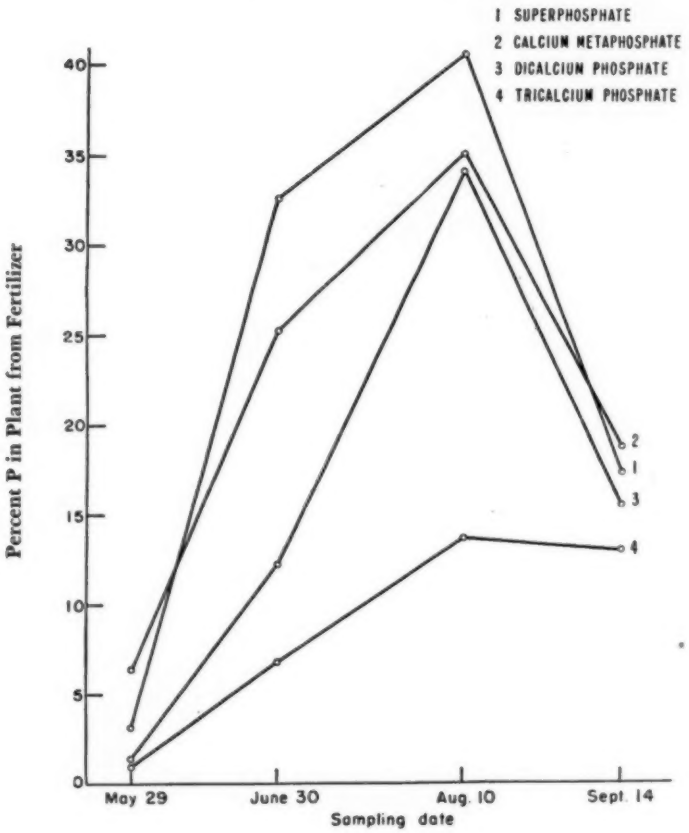
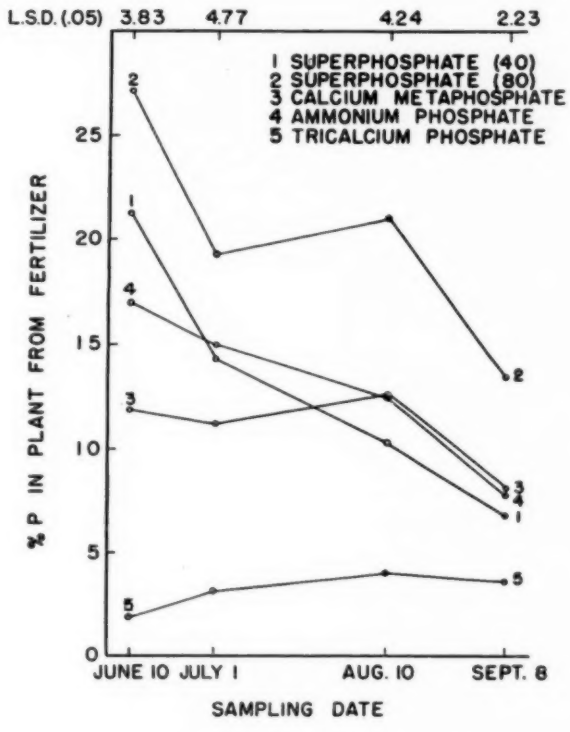


Figure 2. Percentage of Phosphorus in Sugar Beets Derived from Fertilizer as Affected by Source of Phosphorus on Cass Fine Sandy Loam (1948).

by the application of water necessary to give a total of three inches of water in each case. Horizontal as well as vertical movement was determined by measuring the activity in soil samples taken between the furrows.

Movement of phosphorus from the band-placed dry fertilizer was determined by measuring the activity from successive samples beneath the band. All samples were taken with a rectangular sampling tool 1 inch wide, 1 inch deep, and 3 inches long. The soil was sampled parallel to the band.



PERCENTAGE OF PHOSPHORUS DERIVED FROM FERTILIZER BY SUGAR BEETS AS AFFECTED BY SOURCE OF PHOSPHORUS ON FORT COLLINS LOAM

Figure 3.

The activity of all samples was determined as follows: Five grams of soil were spread evenly in a flat container 34 mm in diameter and 5 mm deep. The soil was tamped gently with a 100-gm. weight to give uniform geometry, and the activity determined with an end-window Geiger tube. Absolute amounts of fertilizer phosphorus in each sample were determined by making comparisons with the activity of a 5-gm. sample containing a known amount of radioactive phosphorus fertilizer.

RESULTS AND DISCUSSION

Percentage of Phosphorus in Plant Derived from the Fertilizer

The results for 1948 are shown in Figures 1 and 2 and for 1949 in Figure 3. At all locations and sampling dates, the absorption of phosphorus from alpha tricalcium phosphate was the least. Superphosphate supplied more phosphorus to the plants than calcium metaphosphate in the early stages of growth and more than dicalcium phosphate at all sampling periods.

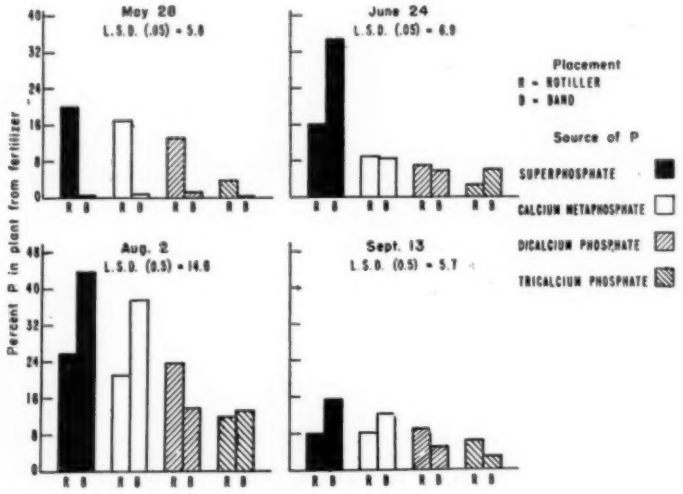


Figure 4. Effect of Placement and Source of Phosphorus on Percentage of Phosphorus in Sugar Beets Derived from Fertilizer on Fort Collins Loam (1948).

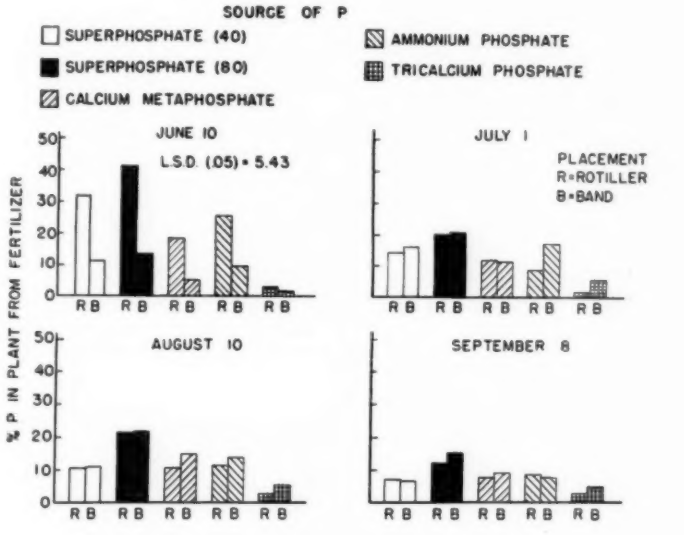
The plants absorbed less phosphorus from ammonium phosphate than from superphosphate the first sampling, but about equal amounts were absorbed from these two fertilizers thereafter.

The uptake of phosphorus from the 80-pound rate of superphosphate was approximately twice as much as from the 40-pound rate for the last two sampling periods. This difference, however, was not reflected in the final yield of beets.

Comparing the results for both years, there is a marked difference in the shape of the curves showing uptake of phosphorus, which is due probably to differences in the amount of rainfall each year. In 1948, only 4.04 inches of rain fell in May and June, whereas 9.31 inches occurred in 1949. Although the first sampling dates are not the same each year, the relative stages of growth are comparable. When the surface four inches of the soil were kept moist almost continuously by the high rainfall in 1949, the plants absorbed

considerably more phosphorus from the fertilizer than in 1948 when the surface soil was usually dry.

After irrigation in 1948, the root activity in the surface four inches of the soil probably was stimulated, causing a pronounced increase in the uptake of phosphorus from the fertilizer. The effect of irrigation in 1949 was not noticeable, since the plants had been well supplied with water all through the early stages of growth. The downward slope of the curves



EFFECT OF PLACEMENT AND SOURCE OF PHOSPHORUS ON PERCENTAGE OF PHOSPHORUS IN SUGAR BEETS DERIVED FROM FERTILIZER ON FORT COLLINS LOAM

Figure 5.

showing uptake of phosphorus with stage of growth (Figure 3) appears to be quite typical when the crop is well supplied with water. As the root system extends throughout the soil, the roots absorb relatively more phosphorus from the soil than from the fertilizers, although this effect probably is due, in part, also to the conversion of the water-soluble phosphorus in the fertilizer to less available forms.

Comparing the uptake of phosphorus from superphosphate and calcium metaphosphate (Figures 1, 2, and 3), it appears that the latter is less available in the early stages of growth, but equal to superphosphate at later growth periods. Possibly the calcium metaphosphate must be hydrolyzed to the orthophosphate before it can be utilized by the plants. The rate of hydrolysis would probably be slower if the soil moisture content were low, i.e., after

Table 2.—Total uptake of phosphorus from the soil, from the fertilizers, and the percentage utilization of the applied phosphorus at the final sampling.

Fertilizer	P_2O_5 applied lbs./A.	P_2O_5 in plants from fertilizer, lbs./A. Sampling, days after planting				P_2O_5 in plants from soil, lbs./A. Sampling, days after planting				Percentage of fertilizer P_2O_5 used
		49	70	110	139	49	70	110	139	
None		.....	.....	.....	.....	0.18	2.60	25.7	45.2	.....
Superphosphate	40	0.059	0.45	3.02	3.90	0.23	2.83	26.7	44.9	9.75
Superphosphate	80	0.087	0.73	7.16	8.70	0.25	3.20	27.2	47.3	10.8
Calcium metaphosphate	40	0.030	0.35	3.61	4.87	0.24	2.89	25.5	45.2	12.2
Ammonium phosphate	40	0.043	0.48	3.65	4.83	0.20	2.77	26.5	45.5	12.1
Alpha tricalcium phosphate	40	0.005	0.10	1.11	2.08	0.26	3.35	28.8	46.7	5.20
L.S.D. (0.05)		0.010	0.15	1.18	1.88	0.06	N.S.[1]	N.S.	N.S.	.....
C.V.[2]		19.5	24.2	26.2	31.9	21.7	17.0	12.2	8.58	.....

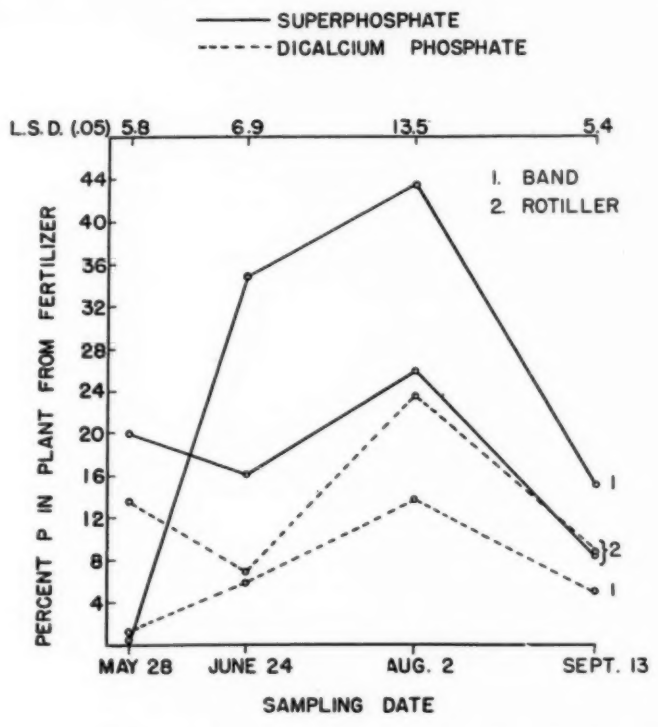
[1] N.S. = not significant.
[2] C.V. = coefficient of variation.

June 24 (Figure 1) the plots were irrigated and the uptake from calcium metaphosphate greatly increased.

Effect of Placement on the Uptake of Phosphorus from the Fertilizers

The uptake of phosphorus from each fertilizer and placement is shown in Figures 4 and 5. The seeds were planted in the rototiller band. Therefore, the roots could contact the fertilizer from the beginning of growth. At thinning time it appears that the roots had not penetrated to the locality of the concentrated band in 1948, although some uptake had occurred in 1949. This comparison of early uptake from the fertilizer may be important on soils low in available phosphorus when the need in early stages of growth is large. In such cases, these data suggest the advisability of placing at least part of the phosphate near the seed.

The effect of placement on uptake of phosphorus varies with the source of phosphorus and with season. In a dry year (1948), the absorption of phosphorus from superphosphate and calcium metaphosphate is much higher from the band than from the rototiller placement, whereas placement has little effect on either dicalcium phosphate or alpha tricalcium phosphate (Figure 6). In a wet year (1949), the effect of placement at thinning time was the same is in 1948, but afterward placement did not affect appreciably the uptake from any of the fertilizers. These results indicate that when comparisons of fertilizer materials or placement are being studied, the moisture status in the surface 4 to 5 inches of soil is a very important factor. It seems probable that when the fertilizer is placed in the top 4 to 5 inches of soil, the effect of moisture will be dependent for the most part upon the amount of rainfall, since in either year the plants were well supplied with irrigation water. These relationships between moisture and phosphorus uptake would be modified, however, by the frequency and manner of irrigation, and the depth of placement of the fertilizer.



PERCENTAGE OF PHOSPHORUS DERIVED FROM FERTILIZER BY SUGAR BEETS AS AFFECTED BY PLACEMENT AND SOURCE OF PHOSPHORUS

Figure 6.

Comparison of Liquid Phosphoric Acid and Treble Superphosphate

The percentage of phosphorus in sugar beets derived from the fertilizer as affected by source and time of application is shown in Figure 7. The late application of treble superphosphate supplied about one-half as much phosphorus to the plants as the early application. Except for the first sampling period, the liquid phosphoric acid furnished about the same amounts of phosphorus to the plant as the early application of treble superphosphate. These results indicate that, if late side-dressings of phosphate are to be made, liquid phosphoric acid would be a better source of phosphorus than band-placed treble superphosphate. Application of the phos-

phorus before or at planting time appeared to be the best method, particularly if the plants lacked phosphorus in the early stages of growth.

Yield increases of sugar beets were not significant; the yields ranged from 11.2 to 11.9 tons per acre. Yield of sugar per acre was not affected by the treatments.

Amount of P_2O_5 Absorbed from the Fertilizer and from the Soil

Total uptake of phosphorus from the soil and from the fertilizer and

Table 3.—Effect of source of phosphorus on yield of sugar beets in tons/acre (1948).

Treatment	Agronomy Farm		Hoffman Farm	
	August 2	October 12	August 10	October 9
None	8.74	19.9	9.48	13.2
Superphosphate	9.68[1]	20.7	9.68	16.7[2]
Calcium metaphosphate	9.83[1]	20.2	9.14	15.1[1]
Dicalcium phosphate	9.46[1]	20.3	8.05	14.3
Alpha tricalcium phosphate	9.17	20.6	8.80	14.1

[1] Significant increase at 5% level compared to check.
[2] Significant increase at 1% level compared to check.

the percentage utilization of the applied phosphorus is shown in Table 2. Except for alpha tricalcium phosphate, the utilization of the applied phosphorus was about the same for all other fertilizers. The crop absorbed 10 to 12 percent of the applied phosphorus. About 9 percent of the liquid phosphoric acid and treble superphosphate applied in a separate experiment was utilized by the sugar beets. At the first sampling date, the amount of phosphorus absorbed from the soil in the fertilized plots was higher than from the check plots.

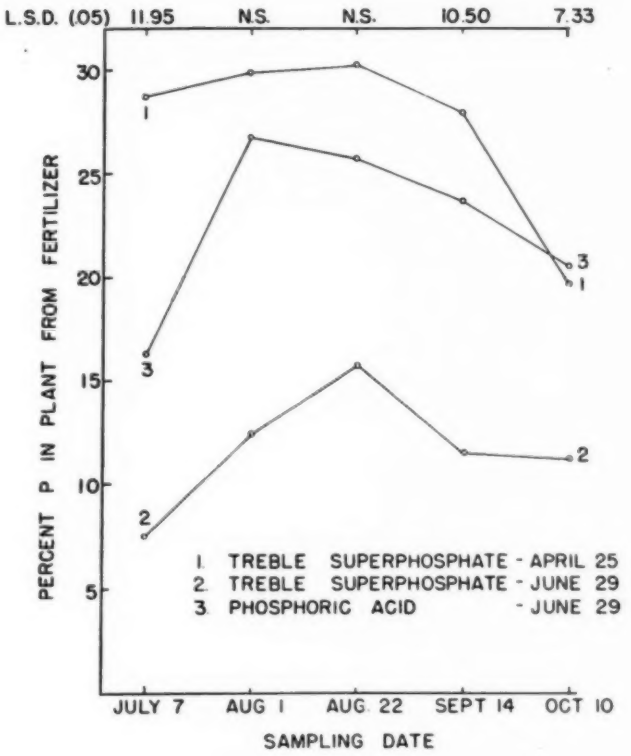
Yields

The differences in the uptake of phosphorus due to source of material and stage of growth should be reflected in yield, unless the plants can obtain their maximum needs for phosphorus from the soil, or if some other growth factor, i.e., moisture or nitrogen, becomes limiting. Moisture tension data were not obtained from these experiments, but each year on the Agronomy Farm a moisture-fertility experiment was conducted adjacent to the radioactive experiment. Irrigations on the radioactive plots were made to correspond with those plots in the moisture-fertility study which received the highest number of irrigations, and were presumably well supplied with

Table 4.—Yield of sugar beets at various stages of growth as affected by source of phosphorus (1949).

Treatment	Sampling Date				
	June 10[3] gms/96′ row	June 30 gms/150′ row	Aug. 10 Tons/A.	Sept. 8 Tons/A.	Oct. 11 Tons/A.
None	37.1	273	8.18	15.0	17.9
Superphosphate (40)	55.8[2]	334	9.73[2]	16.3	18.5
Superphosphate (80)	64.5[2]	408[2]	9.63[2]	16.8[1]	18.7
Calcium metaphosphate	53.4[1]	336	9.65[2]	16.1	18.4
Ammonium phosphate	47.6	345[1]	9.69[2]	17.0[1]	19.3
Alpha tricalcium phosphate	52.8[1]	389[2]	9.39[1]	15.9	18.8

[1] Significant increase at 5% level compared to check.
[2] Significant increase at 1% level compared to check.
[3] Whole plant sampled.



PERCENTAGE OF PHOSPHORUS DERIVED FROM FERTILIZER BY SUGAR BEETS AS AFFECTED BY SOURCE OF PHOSPHORUS ON FORT COLLINS LOAM

Figure 7.

moisture. Nitrogen was probably not a limiting growth factor on the radioactive plots, as indicated by nitrogen level studies in adjoining experiments and by the color of the leaves.

Yields of sugar beets as affected by source of phosphorus at various stages of growth are shown in Table 3 for 1948, and Table 4 for 1949. On August 2 (Figure 1), when the plants contained the largest amounts of phosphorus from the fertilizer, the yield was increased by those fertilizers furnishing the most phosphorus to the plants on the Agronomy Farm. At harvest time, however, the effect of phosphate fertilizer was not significant.

The yields on the Hoffman farm were affected some by variations in stand, but the final yields showed an increase due to superphosphate and calcium metaphosphate. These two fertilizers also supplied the most phosphorus to the plants.

In Table 4, the yields in 1949 tend to show an increase for all fertilizers in the early stages of growth and up to the middle of the growing season. The final yields, however, were not affected significantly by source of phosphorus. The data in Tables 3 and 4, and in Figures 1, 2, and 3 indicate that the same conclusions would be made regarding the availability of

Table 5.—Percentage of phosphoric acid found at various depths applied to surface of of soil (sugar beets).

Depth Inches	Proportion of total P added found at various depths[1]	Depth Inches	Proportion of total P added found at various depths[1]
	percent		percent
0-1	55.0	8-9	1.90
1-2	21.2	9-10	2.23
2-3	6.06	10-11	1.49
3-4	2.97	11-12	0.59
4-5	2.53	12-13	0.41
5-6	1.90	13-14	0.40
6-7	1.41	14-15	0.37
7-8	1.49	15-16	0.11

[1] Each value represents the average of four samples.

the various fertilizers whether or not a yield increase was obtained.

It has been observed commonly that phosphorus affects plant growth most markedly in the early stages of growth. If a soil is on the borderline of deficiency in available phosphorus, the early stimulation of growth may be overcome by the untreated plants after the root systems become well established.

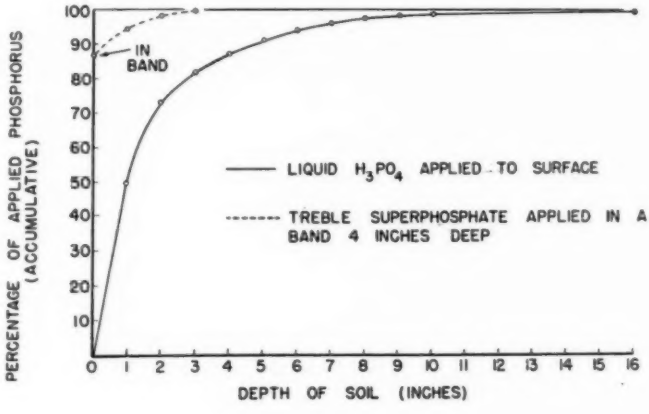
Table 6.—Percentage of total phosphoric acid added found at various depths applied with varying amounts of water (fallow land).

Depth Inches	Acre inches of water applied with H_3PO_4		
	three	one	one-third
	percent[1]	percent[1]	percent[1]
0-1	51.9	49.7	48.5
1-2	21.3	23.4	25.8
2-3	6.40	8.88	8.58
3-4	5.93	5.45	5.31
4-5	4.26	3.89	2.98
5-6	2.84	2.80	2.04
6-7	1.65	2.10	1.79
7-8	0.95	1.48	1.83
8-9	0.95	0.78	1.58
9-10	1.42	0.47	0.89
10-11	1.33	0.47	0.40
11-12	0.57	0.16	0.20
12-13	0.09	0.07	0.10
13-14	0.05	0.07	0.05
14-15	0.05	0.07	0.05
15-16	0.05	0.07	0.05

[1] Each value represents the average of four samples.

Phosphorus Content of Tops

Analysis of the leaves for total phosphorus showed that the phosphorus content was increased over the check plots by superphosphate and calcium metaphosphate at the last three sampling periods on both locations in 1948. The phosphorus content of the leaves varied somewhat with sampling date in 1949. Only the higher rate of superphosphate consistently increased the phosphorus content at all sampling periods. All fertilizers except alpha tricalcium phosphate increased the phosphorus content of the leaves over the check at the last sampling period (September 8).



MOVEMENT OF PHOSPHORUS APPLIED AS LIQUID PHOSPHORIC ACID AND TREBLE SUPERPHOSPHATE

Figure 8.

The phosphorus content of the leaves was not affected significantly by the application of liquid phosphoric acid or treble superphosphate.

Movement of Phosphorus

The movement of liquid phosphoric acid applied to land in sugar beets and on fallow land is shown in Tables 5 and 6. Movement of phosphorus below twelve inches was very slight (Figure 8). At least 85 percent of the applied phosphorus was found in the top four inches of the soil. The amount of water applied with the phosphoric acid had little effect on the movement of the phosphorus. The results on the fallow land were essentially the same as where the sugar beets were growing.

Tests were made under both conditions to eliminate possible contamination of the soil samples by the sugar beet roots, since radiophosphorus ab-

sorbed near the surface subsequently could be translocated downward to roots at lower depths. Ulrich, et al. (13) added phosphoric acid containing radiophosphorus to the Aiken loam. The phosphorus penetrated about 12 inches and 75 percent was found in the top four inches of the soil.

The movement of phosphorus from band-placed treble superphosphate (Table 7) was considerably less than from the liquid phosphoric acid. Very little of the treble superphosphate moved beyond three inches. The greater movement of phosphorus from the early application was caused probably by an additional 9.31 inches of rain which fell between May 2 and June 29. The soil samples were taken July 23.

There was no appreciable horizontal movement of the liquid phosphoric acid. Soil samples taken on top of the ridge between furrows, at the center of the ridge, or in the ridge at a position horizontal with the bottom of the furrows showed no radioactivity. The fertilizer would have to move from 4 to 7 inches in order to reach the center of the ridge. When the phosphorus was applied, the furrows were filled with water to about 50 percent of their capacity.

Table 7.—Percentage of total treble superphosphate added found at various depths applied in a band four inches deep.

Depth inches below band	Date of application May 2	June 29
	percent[1]	percent[2]
in band	86.7	95.7
0-1	7.5	2.5
1-2	3.9	1.1
2-3	1.9	0.8

[1] Average of four samples
[2] Average of six samples.

SUMMARY

The effect of source of phosphorus, placement, rate, and time of application on its ultization by sugar beets was studied.

Calcium metaphosphate was less available than superphosphate in the early stages of growth, but about equal thereafter. Ammonium phosphate (11-48-0) and superphosphate were about equally available. Alpha tricalcium phosphate supplied the least amount of phosphorus to the crop at all stages of growth.

Liquid phosphoric applied June 29 was about equal to treble superphosphate applied May 2, but higher than treble superphosphate applied June 29.

Placement of the fertilizer near the seed increased markedly the uptake of phosphorus at thinning time compared to band placement. In later stages of growth, however, the band placement supplied more phosphorus than the rototiller placement in a dry year, and about equal amounts in a wet year.

The crop absorbed 10 to 12 percent of the applied phosphorus, except with alpha tricalcium phosphate.

Phosphorus applied in the irrigation water moved downward at least 12 inches, although 85 percent of the total applied was found in the top

four inches of soil. Phosphorus applied as treble superphosphate in a band four inches deep moved downward about three inches below the band.

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Tracing During the Growing Season the Nitrogen, Phosphate, Potash and Refractometer Solids of Beets from Plots Receiving Varying Amounts of Nitrogen

M. G. FRAKES AND ALAN CHILDS[1]

A total of 45 test plots was established on sugar beets during the 1949 growing season. These plots received varying amounts of nitrogen ranging from 40 pounds to 200 pounds of elemental nitrogen per acre in mulitples of 40 pounds. Several sources of nitrogen were compared. Among these were anhydrous ammonia, sulphate of ammonia, ammonium nitrate and ammonium chloride.

Nitrogen was applied as a side-dressing in July after blocking and thinning. Starting August 1, the relative amounts of nitrogen, phosphorus and potash were determined at weekly intervals by means of tissue tests. Refractometer readings were made at weekly intervals starting August 15 and interpreted into approximate sugar content.

When anhydrous ammonia was applied at the rate of 40 pounds of nitrogen per acre during early July, the sugar beet plants showed a lack of nitrate nitrogen, as determined by tissue tests, in about six weeks depending upon available nitrogen in the soil. Added amounts of nitrogen in 40-pound increments were available to beets for about two weeks longer for each 40 pounds added over and above the original 40. For example, good nitrate tests were obtained for a period of two weeks longer for a 40-pound application over no application, for an 80-pound application over 40 pounds and 120-pound application over 80 pounds.

When different forms of nitrogen carriers were used at equal rates of elemental nitrogen per acre, the tissue tests indicated plant utilization of ammonia nitrate first, sulphate of ammonia second, with anhydrous ammonia a close third and ammonium chloride last. Blank tests occurred indicating lack of available nitrogen to plants in the same order. Ammonium nitrate showed up in tissue tests in less than a week after application and also left quickly. Ammonium chloride was very slow to show up in tissue tests.

The test for excessive nitrate in tissues was never very high where ammonium chloride was used and lasted much longer, up to six weeks longer, than any other nitrogen-carrying compound. It was interesting to note that, when tissue tests indicated an accumulation of nitrate nitrogen, the percent of sugar was three to four points lower than in beets from check plots which received no nitrogen side-dressing, and showed no excess of nitrate in the leaf tissues. Such beets low in sugar will catch up to beets having higher sugar content in approximately ten days after the petioles give a blank test for nitrate nitrogen indicating the available supply of nitrogen is becoming limited.

[1] Agricultural Research Director and Field Assistant, Michigan Sugar Company.

Table 1 shows the relationship between tissue tests for nitrate nitrogen and sugar content. The elemental nitrogen per acre was applied in the form of anhydrous ammonia as a side-dressing at the time of blocking and thinning.

Table 1.

	August 29		Sept. 17		Oct. 1		Oct. 8	
N_2 per A	Tissue Test	% Sugar	Tissue Test	% Sugar	Tissue Test	% Sugar	Tissue Test	% Sugar
0	Blank	16.0	Blank	16.5	Blank	17.0	Blank	17.8
40 lb.	Low	13.0	Blank	14.5	Blank	17.0	Blank	17.5
80 lb.	Med.	12.0	Trace	13.0	Blank	17.5	Blank	18.0
120 lb.	High	13.0	Low	14.0	Trace	13.0	Blank	17.0

This table indicates the caution required to apply only enough nitrogen so that it will be used by the sugar beets by at least two weeks prior to harvest. This amount will obviously vary with the ability of the soil to supply nitrogen to the crop throughout the growing season. This table is indicative of the reaction of all nitrogen carriers used with the exception of ammonium chloride. It took a considerably longer period for nitrates to show up in the plants as determined by tissue tests from those plots receiving ammonium chloride than from any other nitrogen carrier. These tests never got to a point where they indicated a high nitrate content. Also, it is interesting to note that even though there was a test for nitrate nitrogen in the tissues of beets grown on plots receiving ammonium chloride, their sugar content was not affected adversely as it was on plots receiving other nitrogen carriers.

The relative phosphate content of plants, as indicated by tissue tests, was variable throughout the growing season and showed no definite trends. Relative potash content of plants showed a tendency to diminish with nitrate nitrogen although not nearly as fast. From observations relative to this work, it has been concluded that some very interesting relationships could be observed between plant nutrients and sugar content if such tests were designed so that both tissue tests and soil tests could be made simultaneously at weekly intervals throughout the growing season. It is also believed that as a result of this work, and other work conducted by our research staff, it may be advisable to conduct tissue and soil tests on crops for information concerning proper management and fertilization for crops to follow. It is on this basis that further tests will be made in 1951.

Nutritional Status of Sugar Beets As Revealed by Chemical Analyses of Petioles[1]

JAY L. HADDOCK[2]

Chemical analyses of soils and plants have been both intensive and extensive since the time of Davy, De Saussure, Lawes, and Liebig. Although much information has been obtained by the vast amount of effort expended to wrest from nature her secrets of soil fertility and plant nutrition, this entire field of knowledge is still highly empirical. The kinds of nutrients necessary for plant growth have been well established. The effort currently being exerted on soil tests and plant tissue tests is towards establishing quantitative nutrient requirements.

Agronomists and plant physiologists have studied the factors influencing the absorption and assimilation of plant nutrient elements. Since this paper deals principally with the absorption of nitrogen and phosphorus, literature citations will be limited to this field.

Excellent reviews of research work dealing with plant analyses have been provided (10)[3], (11), (19), (20). Likewise, summaries of research dealing with absorption and assimilation of nitrogen compounds have been published (14), (4), (12), (1), (2). Special reference to nitrogen and phosphorus composition of the sugar beet is also available (8), (9), (5), (3), (18), (20), (17).

It is generally recognized that nitrogen enters the plant through the fine roots, largely as nitrate-nitrogen. Evidence is available indicating that ammonia-nitrogen may at times constitute a considerable proportion of the total nitrogen entering plants, with nitrite and organic forms of nitrogen playing minor roles. Likewise, here is general understanding that phosphorus is absorbed largely as inorganic orthophosphate.

Nitrate-nitrogen is in a highly oxidized state while protein nitrogen is in a highly reduced condition. The process involved in this transformation of nitrogen from inorganic to organic form has not been established conclusively. It is definitely an endothermic reaction. The reduction of nitrates to organic nitrogen is generally assumed to occur in the leaves or other

Figure 1. (see page 335). Seasonal NO_3-nitrogen content of sugar beet petioles with four different commercial fertilizers.

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[1] Contribution from the Division of Soil Management and Irrigation, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Dept. of Agriculture, in cooperation with the Utah Agricultural Experiment Station, Logan, Utah.

[2] Soil Scientist, Division Soil Management and Irrigation.

[3] Figures in parentheses refer to literature cited.

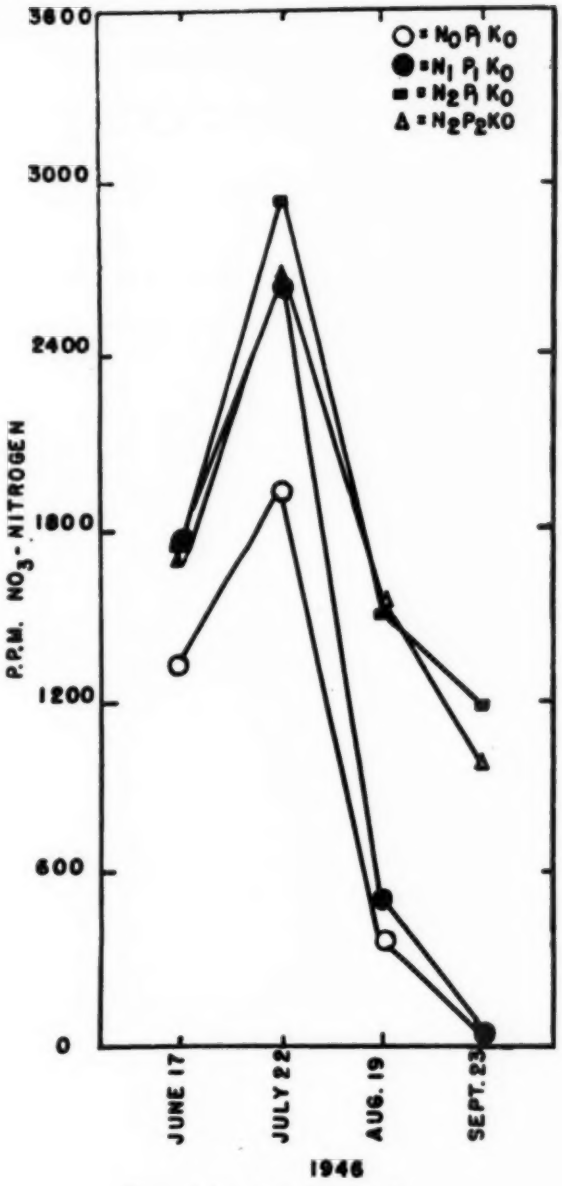

Figure 1 (see preceding page).

aerial portions of plants where the energy from sunlight is available. There is conclusive evidence that under some conditions and with some plants reduction of nitrates and their synthesis to amino acids occurs in the roots. This process may be quite complete in some plants (15), (4), (13), (12). It appears to be of some consequence in the well-developed beet root (21).

It is by no means certain that the nitrate-nitrogen content of sugar beet petioles will give one a complete picture of the nitrogen-nutritional-status of the sugar beet plant. It is quite probable that some of the nitrate-nitrogen is synthesized in the roots of sugar beets to soluble organic nitrogen compounds and moved through the petioles to the aerial portions of the plant for complete assimilation. To the extent this is true nitrate determinations fail to give the complete picture of the nitrogen nutritional status of the plant. Nevertheless, most of the tissue tests now in current use are based upon nitrate-nitrogen determinations in the petioles or other portions of the plant (16), (10), (20), (15).

MATERIALS AND METHODS

The objective of this study was to follow the effects of various irrigation, fertilizer, and spacing treatments on the uptake of specific nutrients (nitrates and phosphates) by the sugar beet plant. The data presented in this paper were obtained incident to a study of the interrelations of soil moisture, plant population, and soil fertility level to yield and quality of sugar beets.

The procedures used in this study for sampling, drying and extracting the plant materials are similar to those suggested by Ulrich (19). Some modifications were made in the chemical determinations.

This study was conducted on Millville fine sandy loam in 1946, and Millville silt loam in 1947 and 1948. Both soils are well-drained. All plots were uniformly sprinkle-irrigated twice in 1946 (June 26 and July 15) and three times in 1947 (April 18, May 6, and June 26) before soil moisture variables were initiated. Commercial fertilizers and manure treatments used are symbolized and described as follows:

N_0—No nitrogen.
N_1—80 pounds nitrogen per acre.
N_2—160 pounds nitrogen per acre.
P_0—No phosphoric acid.
P_1—100 pounds phosphoric acid per acre.
P_2—200 pounds phosphoric acid per acre.
M_0—No manure.
M_1—15 tons barnyard manure per acre.

Nitrate-nitrogen Content of Sugar Beet Petioles

The analytical data on the chemical composition of the sugar beet petioles are presented graphically. By means of these graphs one can obtain a fair estimate of the nutritional status of the sugar beet plant at various periods during the growing season. Ulrich (17) (20), has established a value of 600-800 parts per million of phosphate-phosphorus in sugar beet petioles as the critical level. For nitrate-nitrogen the critical level has been set at about 1,000 parts per million.

Figure 2. (see page 337). Seasonal NO_3-nitrogen content of sugar beet petioles with three different commercial fertilizers.

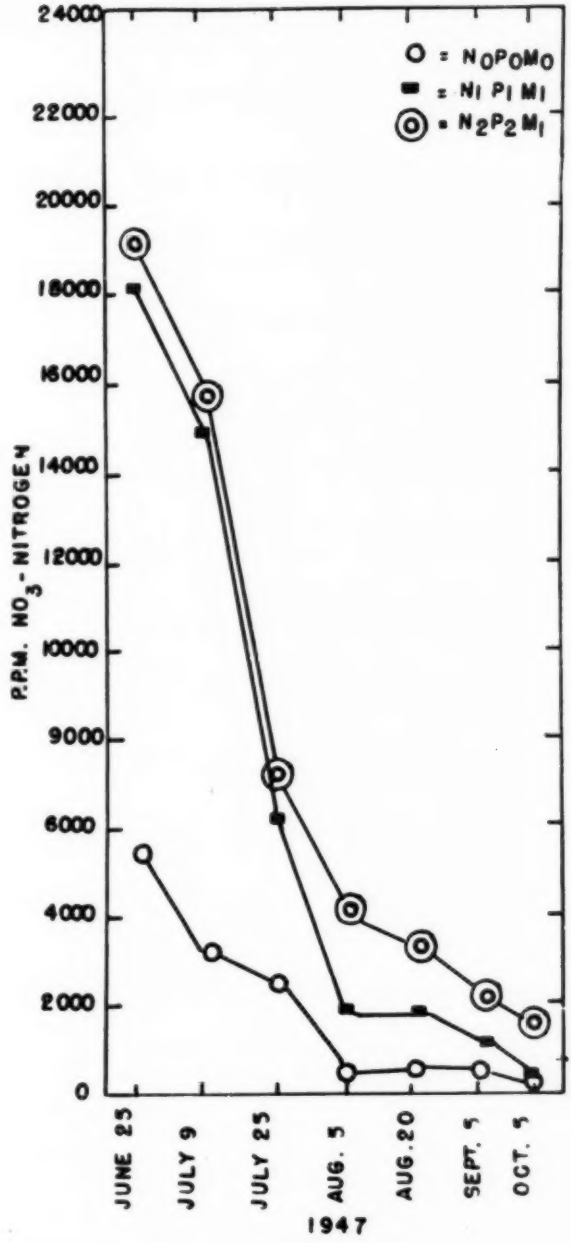

Figure 2 (see preceding page).

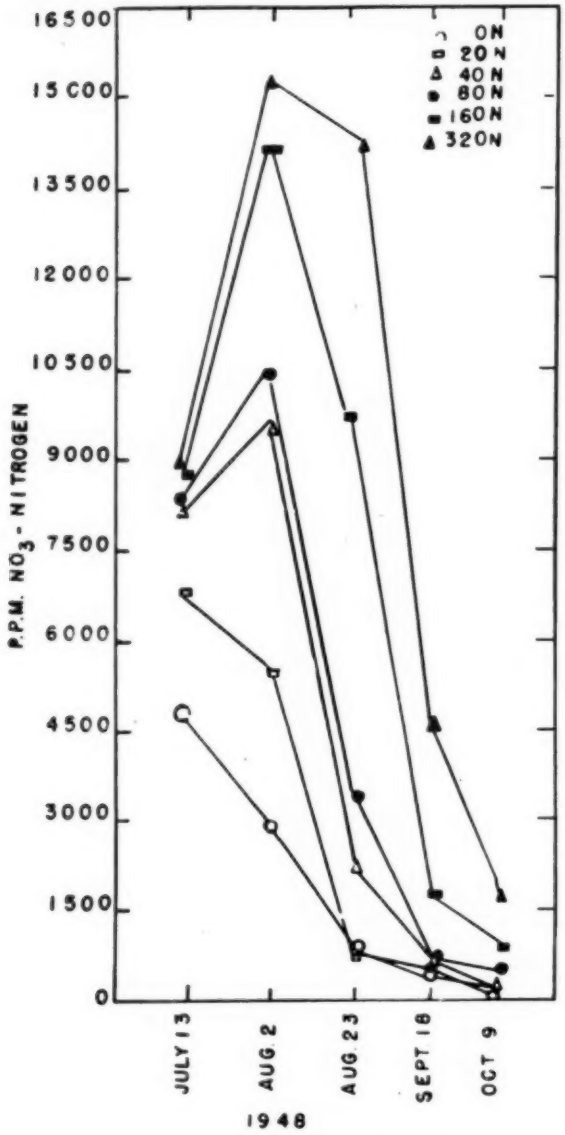

Figure 3. Seasonal NO_3-nitrogen content of sugar beet petioles with six levels of commercial nitrogen.

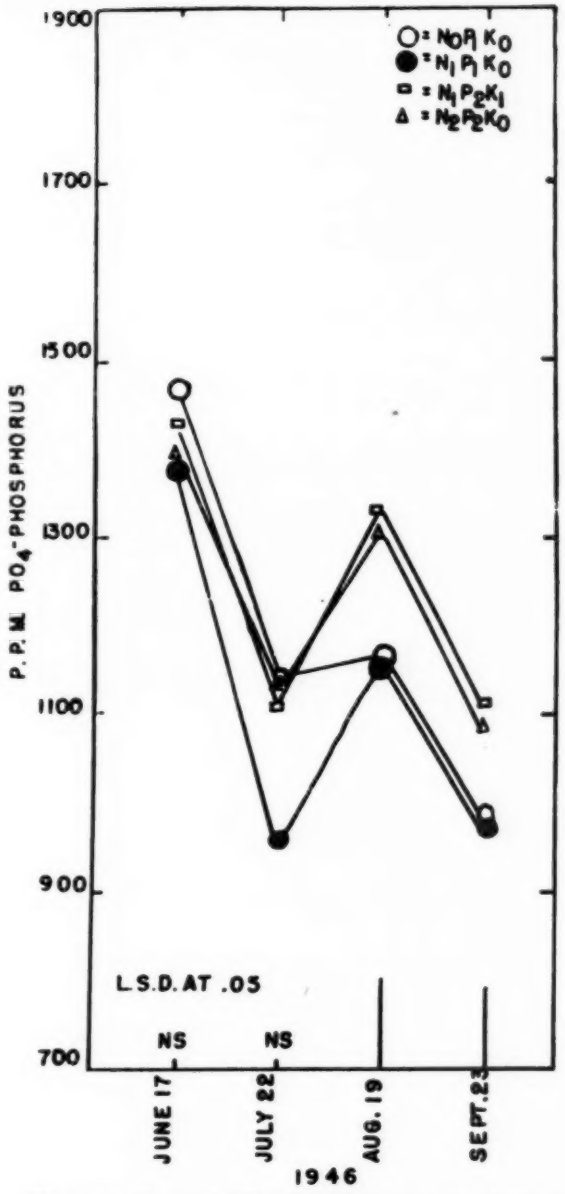

Figure 4. Seasonal PO_4-phosphorus content of sugar beet petioles as influenced by commercial fertilizers.

Data on the yield and quality of sugar beets as influenced by fertilizers, plant population, and soil moisture may be obtained by referring to previous publications (6), and (7). This information may be of value to those interested in comparing petiole composition and yield.

The data presented in the figures which follow are means of all treatments used in the experiment, other than those being compared in each figure.

The data presented in Figures 1, 2 and 3 are what would be expected if fertilizer materials supplied to the soil were actually available to sugar beet plants. Significant differences between fertilizer treatments were obtained at all sampling dates.

It will be observed in Figure 1 that petioles of plants taken from plots receiving no nitrogen were relatively low in nitrogen throughout the season, while petioles of plants which received large quantities of nitrogen were relatively high. Likewise, the data in Figure 2 show that without additions of commercial nitrogen to soils low in available nitrogen, plant petioles will tend to be relatively low all season. It is interesting to observe the wide difference in the composition of petioles from plants receiving no commercial nitrogen and those receiving 80 or 160 pounds of nitrogen per acre (N_1 and N_2). The small differences in the composition of petioles from plots receiving 80 and 160 pounds of nitrogen are also of much interest. The yields of sugar beets on these plots were 20.3, 25.8, and 26.0 tons per acre for 0, 80, and 160 pounds of nitrogen respectively.

The data in Figure 3 are of considerable interest in that the six increments of nitrogen fertilizer show successive increases in nitrate-nitrogen content in the sugar beet petioles. All show relatively low nitrate-nitrogen content at the October sampling. There were no significant differences in yield beyond the nitrogen treatment of 20 pounds per acre. Apparently luxury consumption of nitrogen occurred on the four highest fertilized plots.

The data in Figures 4, 5, and 6 show the effect of various fertilizers upon the phosphorus content of sugar beet petioles throughout the growing season. Here again, one may observe a phenomenon which is neither new nor striking, but nevertheless interesting. The percentage composition of phosphorus found in the sugar beet petiole may depend somewhat upon the amount of available nitrogen in the soil. Confirmation of this is shown in Figure 4. Although the same amount of phosphorus is available in the treatments $N_0P_1K_0$ and $N_1P_1K_0$, there is always a larger percentage of phosphorus in petioles taken from plots receiving $N_0P_1K_0$ than from those receiving $N_1P_1K_0$. This is shown more convincingly in Figure 5. It will be noted that the same amount of commercial phosphorus is applied with treatments $N_0P_1M_1$ and $N_2P_1M_0$. Likewise, when one compares the composition of petioles taken from plots receiving $N_2P_1M_0$ with petioles taken from plots receiving $N_2P_2M_0$, it will be seen that petioles from plots receiving $N_2P_2M_0$ contain significantly more phosphorus than petioles from plots receiving the same amount of nitrogen and one-half as much phosphorus ($N_2P_1M_0$).

Figure 5 (see page 341). Seasonal PO_4-phosphorus content of sugar beet petioles as influenced by commercial fertilizers.

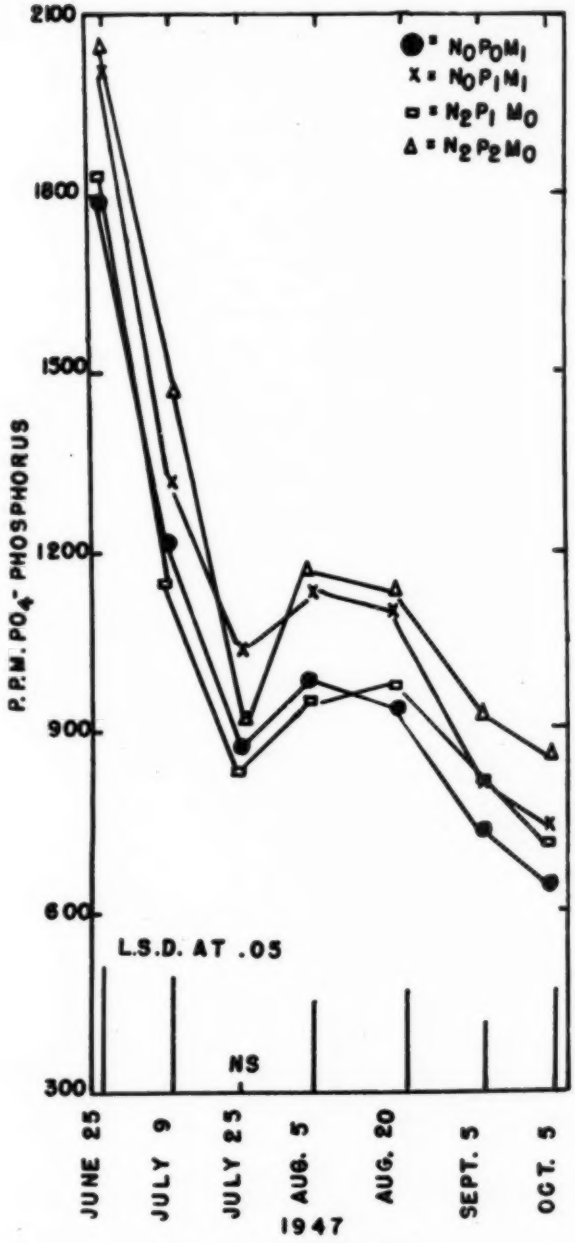

Figure 5 (see preceding page).

It will be observed in Figure 6 that there is a tendency for petioles from plots treated with $N_1P_1M_1$ to contain more phosphorus than from plots treated with $N_2P_1M_1$. Petioles from untreated plots in 1948 tended to show less phosphorus than those from phosphorus-treated plots, even though nitrogen was present as part of the treatment.

From observations noted above one must expect the phosphate-phosphorus content of sugar beet petioles to vary with the age of the plant and season of the year as well as the available nitrogen and phosphorus in the soil.

It has been shown in work at the Utah Station that the uptake of phosphorus is hindered to a much greater extent than the uptake of nitrogen by high soil moisture tension.

Because of limited space it is not possible to present data on the effects of plant population and soil moisture tension on petiole composition. These data will be published elsewhere.

Figures 7 and 8 are presented in this paper with the hope that the data given may be useful to those who may be using either green or dry tissue analyses alone. A considerable amount of valuable and reliable information may be obtained from either dry or green plant tissue analyses. Correlation is far from perfect but about the same general conclusions would be drawn from a study of either set of data. There appears to be less fluctuation from sample to sample taken from the same plot with the dry tissue than with the green tissue. Where a large number of samples must be run it is often more convenient to prepare the dry samples at one time and analyze them at another. The big advantage for green tissue analysis is that one can follow current changes in plant nutrition.

DISCUSSION

The data presented in this paper were obtained incident to a detailed study of the influence of several controllable and measurable plant growth factors upon the yield and quality of sugar beets. Since critical levels for both phosphate-phosphorus and nitrate-nitrogen had been established for sugar beet petioles, it was assumed that these levels might be used as a measure of the adequacy or inadequacy of the several treatments used in field experiments. Frequently treatments are applied to field or greenhouse pot experiments without measurable yield response. One is left to guess whether lack of response is a result of unavailability or failure of the particular treatment to stimulate yields under the condition of the experiment.

If one plans to use petiole analysis as an indication of soil fertility or nutritional status conditions he must certainly keep in mind the influence of seasonal changes. Ths is a very striking phenomenon even though petioles of the same physiological age are used. One should give some consideration to soil moisture conditions, plant population, and the relative abundance of other available plant nutrients in the soil. The seasonal factor is by far the most important factor but the other factors mentioned are not unimportant.

One may well inquire as to the significance of the rapid seasonal decrease in nitrate-nitrogen and phosphorus. There are at least two things

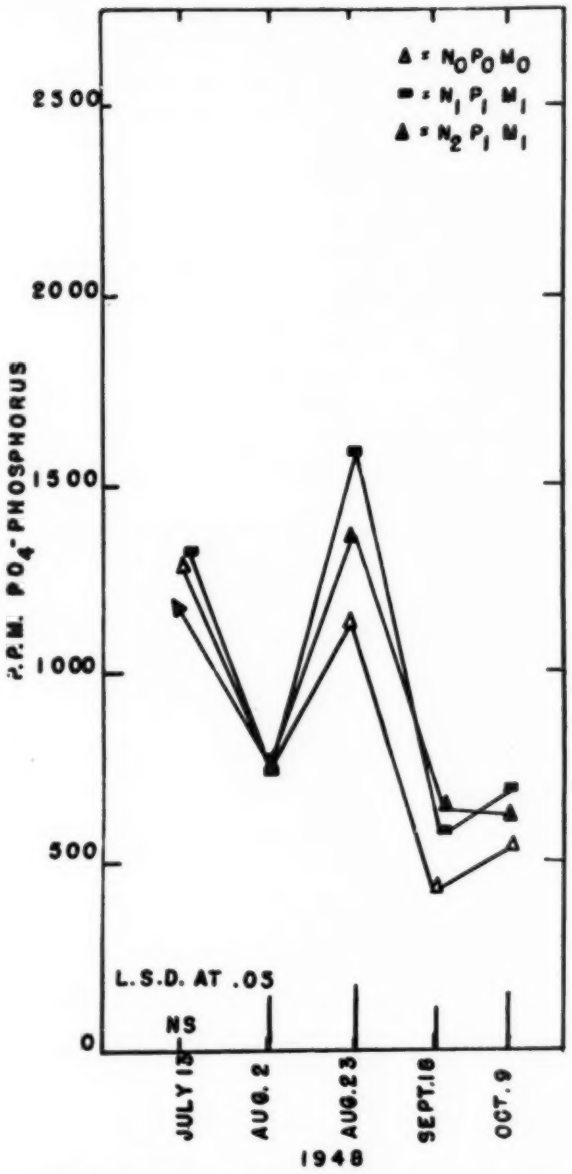

Figure 6. Seasonal PO_4-phosphorus content of sugar beet petioles as influenced by manure and commercial fertilizers.

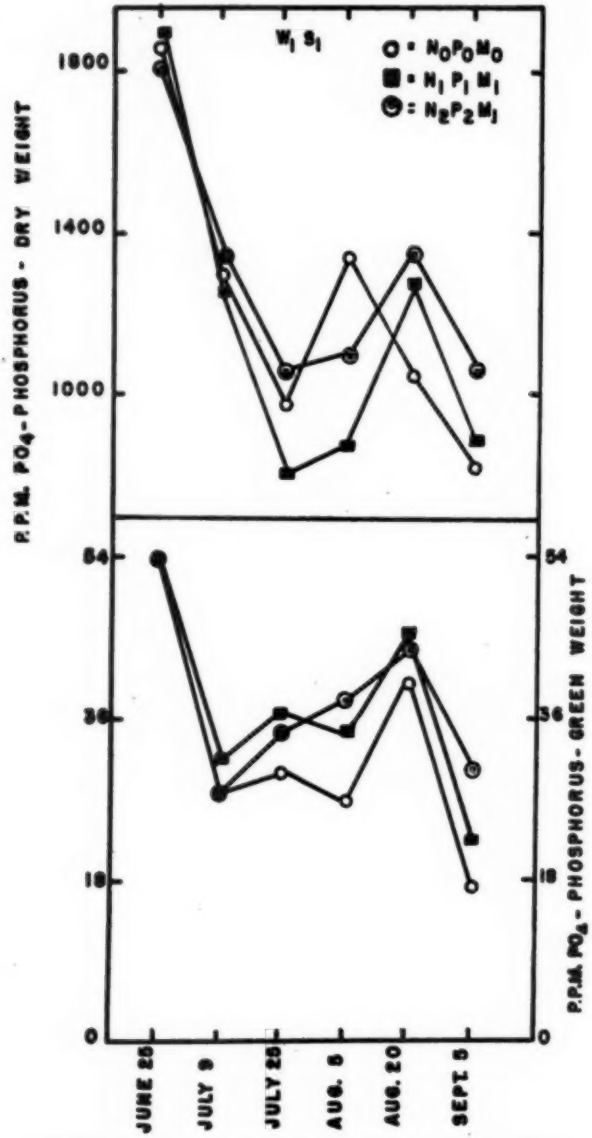

Figure 7. Seasonal PO_4-phosphorus content of sugar beet petioles as determined on oven dry samples and fresh green samples with three fertilizers (1947).

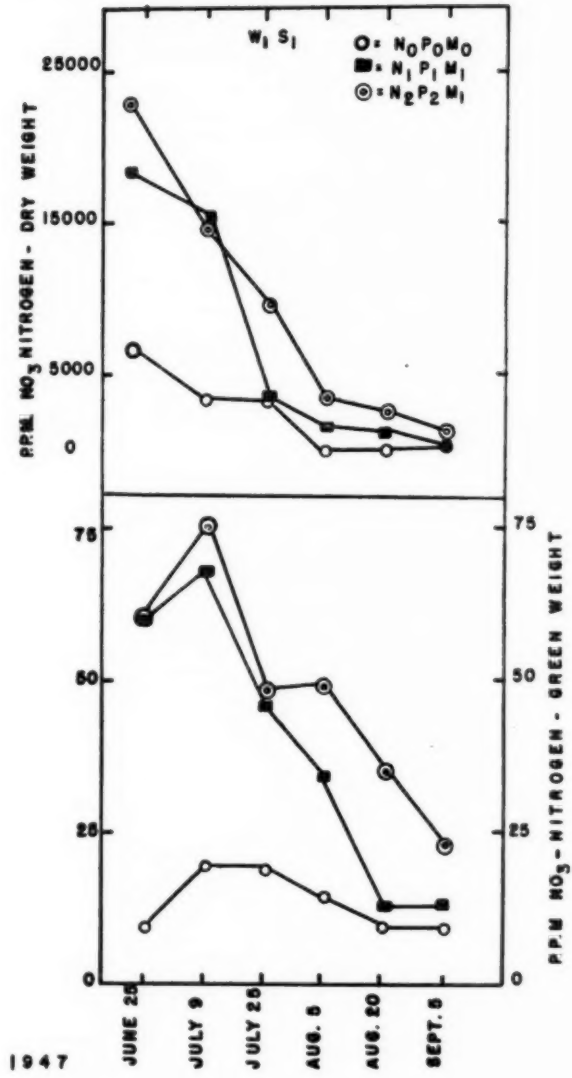

Figure 8. Seasonal NO_3-nitrogen content of sugar beet petioles as determined on oven dry samples and fresh green samples with three fertilizers (1947).

which may account for this. *First, petioles of the same physiological age increase in size as the season advances.* This increased plant material may have the effect of diluting the chemical composition. *Second, as the season advances the sugar beet roots grow larger and become charged with an abundance of soluble sugars.* This may be a favorable environment for reduction of nitrates to amino nitrogen. Whereas nitrogen may enter the plant and move up the petioles principally as nitrate-nitrogen early in the season it may be reduced in the root and move up the petioles largely as amino or noncolloidal organic nitrogen in September and October. Evidence obtained at the Logan Station strongly supports the latter possibility. It is entirely probable that some dilution may occur. Plans are underway to study the effect of dilution.

SUMMARY AND CONCLUSION

1. Irrespective of moderate variability in soil moisture conditions, plant populations and fertilizer treatment sugar beet petioles are relatively high in NO_3-nitrogen early in the season. The percentage of NO_3-nitrogen decreases rapidly from June to the last of July, after which the rate of decline in NO_3-nitrogen composition becomes very gradual until it reaches a minimum in October.

2. The general seasonal trend in NO_3-nitrogen composition of sugar beet petioles described in (1) above may be modified slightly by extreme soil-moisture conditions and available plant nutrients.

3. The PO_4-phosphorus content of sugar beet petioles follows the same general seasonal trend as described in (1) above for NO_3-nitrogen. The absolute amount of PO_4-phosphorus is much smaller than the NO_3-nitrogen content early in the season but becomes greater by harvest time.

4. The uptake of phosphorus by the sugar beet plant is influenced to a much greater extent by the amount of available nitrogen in the soil than is the uptake of nitrogen influenced by the amount of available phosphorus.

5. A fair picture of the nutritional status of sugar beet plants as measured by NO_3-nitrogen and PO_4-phosphorus can be had by chemical analysis of either dry plant tissue or green tissue.

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Plant Tissue Testing as a Guide to Side-Dressing Sugar Beets[1]

L. S. ROBERTSON[2]

The testing of green plant tissue is recognized as a reliable method for determining the nutrient status of plants (3, 5)[3]. In view of the fact that tissue testing kits are now widely available and easy to use, it is possible for sugar beet growers to make a much more efficient use of commercial fertilizer. This is particularly true where fertilizer is applied as a side-dressing. Such delayed applications are for the purpose of supplying nutrients as they are needed during the growing season and should be considered as supplementary to the planting time application.

From a theoretical point of view, side-dressing may be practical if: (1) inadequate applications of fertilizer have been made at planting time; (2) if growth characteristics and (or) plant tissue tests indicate a low plant nutrient status; (3) if the soil has a high nutrient fixing power; (4) or if there occurs a low efficiency in fertilizer consumption by a crop.

The purpose of this investigation was to determine the practicality of using rapid tissue test information as a guide for the application of supplemental fertilizer as a side dressing.

Methods and Procedures

Plant tissue tests were made with a Simplex Soil and Plant Tissue Testing Kit[4]. These tests measure the unassimilated nutrients, thus indicating whether or not the plant is obtaining sufficient nutrients at the time the tests are made. The results of tests in the field were recorded as H (high), M (medium), L (low), and B (blank).

For the most part side-dressings were made in fields where the beet leaves tested low or blank for a given nutrient. The fertilizer was applied with an experimental garden type of side-dresser[5] which treats two rows at a time. For the elements other than nitrogen, the fertilizer was placed as close to the row as possible without physical injury to the plants and from one to two inches deep. The ammonium sulfate, in some cases, was placed as just described. In other experiments it was placed on the surface of the soil within two inches of the plants. Unless one is careful it is possible when applying fertilizer as a side-dressing to injure the beet roots so seriously that the fertilizer application may fail to increase yields. Sugar beet planters have been used successfully for placing fertilizer to the side of the row.

Results and Discussion

The results of these experiments are shown in Tables 1 through 4. For

[1] Contribution from the Soil Science section, Michigan Agricultural Experiment Station, East Lansing, Michigan. Authorized for publication by the Director as journal article No. 1119 of the Michigan Agricultural Experiment Station.

[2] Assistant Professor (Research) Soil Science.

[3] Numbers in parentheses refer to literature cited.

[4] Kits may be obtained from Soil Science Department, Michigan State College, East Lansing, Michigan.

[5] Cooperative project between USDA Agricultural Engineers and Soil Science Department.

the most part these data are the results of tissue tests and yields on individual farms and are intended to illustrate certain points in regard to side-dressing.

If tissue tests indicate a "high" amount of the nutrients nitrogen, potassium and phosphorus, there is no reason to expect that supplemental applications of these elements would increase sugar beet yields. The data presented in Table 1 show that in a field where tissue tests for nitrogen, phosphorus and potassium were high fertilizers applied as a side-dressing did not increase yields or percentages of sugar. No exceptions to this have been observed. These plots were located on a Brookston clay loam soil and were all fer-

Table 1.—The effect of side-dressing with ammonium sulfate and 0-20-20 fertilizer upon sugar beet yields.

Date of Side-Dressing	Pounds Per Acre Ammonium Sulfate	0-20-20	Tissue Test N	P	K	Yield[1] T/A	Percent[1] Sugar
July 18	200	0	H	H	H	11.8	17.5
July 18	500	400	H	H	H	12.4	16.9
July 18	200	400	H	H	H	11.8	16.9
July 18	500	0	H	H	H	11.8	16.8
July 18 and Aug. 7	200	0	H	H	H	11.1	17.1
July 18 and Aug. 7	500	0	H	H	H	12.3	16.9
July 18 and Aug. 7	200	400	H	H	H	12.3	17.3
July 18 and Aug. 7	500	400	H	H	H	11.4	17.2
No side-dressing			H	H	H	11.6	17.2

[1] No significant difference at 5 per cent level.

tilized uniformly at planting time. The crop previous to sugar beets was two-year-old alfalfa.

The data reported in Table 2 show that nitrogen side-dressing did increase yields in fields where the tissue test for nitrogen was low or blank, but they did not cause an increase in yield in a third field where the test

Table 2.—The effect of ammonium sulfate on the yield of sugar beets which varied in their content of nitrate nitrogen at the time of side-dressing[1]

Pounds Per Acre of Ammonium Sulfate Side-dressed	Ferden Farm[2] Test for Nitrogen	Yield Tons/A	% Sucrose	Rader Farm Test for Nitrogen	Yield Tons/A	% Sucrose	Talladay Farm Test for Nitrogen	Yield Tons/A	% Sucrose
0	B	9.10	19.2	L	7.35	15.0	M	16.6	16.1
200		12.39	19.0						
250								15.3	16.4
375					8.43	15.7			
500								17.7	15.5
L.S.D.—5% level		1.1	N.S.[3]		1.0	N.S.		N.S.	N.S.

[1] Tests for phosphorus and potassium were high.
[2] Crop sequence data—sugar beets after timothy.
[3] N. S.—not significant at 5 per cent level.

was medium at the time the fertilizer was applied. There is a possibility, of course, that a medium test could be followed with a beneficial response to applied nitrogen. If previous tests in the same field were high the medium test could be an indication that the beets were using nitrogen more rapidly than it was being made available in the soil. If this were the case the beets

might later need supplemental nitrogen for optimum growth.

The data shown in Figure 1 indicate the relationship between plant tissue tests and response to side-dressing with nitrogen. These were obtained from the crop sequence results on the Ferden farm in 1948 (6). Various

Table 3.—Sugar beet yields as affected by side-dressings of manganese and potassium and a manganese spray.

	Tons per acre	% Sucrose
Wauseon sandy loam[1]		
Not side-dressed	17.8	18.15
100 pounds $MnSO_4$ side-dressed	22.1	17.8
100 pounds KCl side-dressed	21.0	18.2
Berrien loamy fine sand[2]		
Not side-dressed	10.8	
100 pounds $MnSO_4$ side-dressed	17.8	Not
5 pounds $MnSO_4$ sprayed	16.8	Determined

[1] Side-dressed June 11.
[2] Side-dressed and sprayed August 4.

preceding legumes, legume-grass mixtures, grasses and grains supplied different amounts of nitrogen for the sugar beets. These were reflected in the tissue tests, side-dressing responses and sugar beet yields. Higher tissue tests for nitrogen were accompanied by lower response from side-dressings.

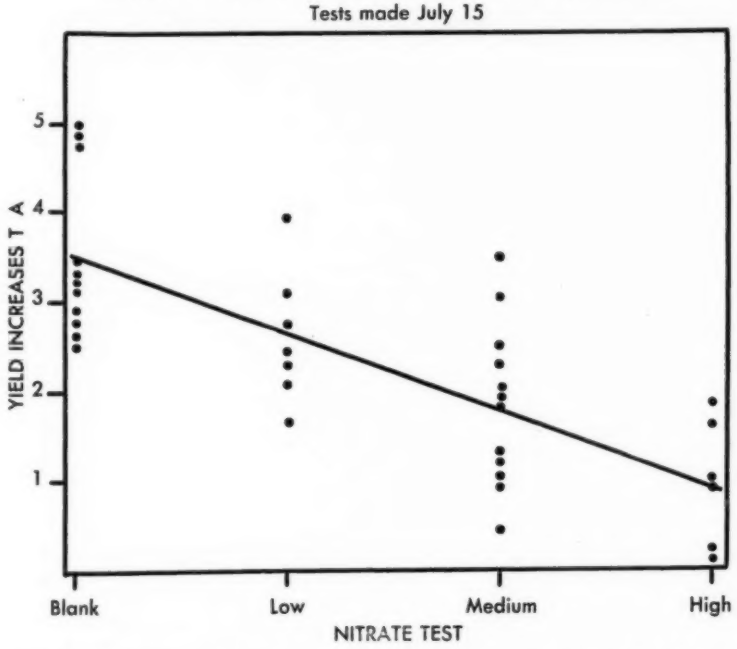
A few instances have been noted in which beets which tested low in nitrate did not respond favorably to an application of nitrogen as a side-dressing. In such cases, the soil had not been managed properly and was not in a desirable physical state. Tissue tests do not indicate this condition and unfortunately there are no dependable rapid tests for the measurement of soil tilth.

Theoretically, nitrogen side-dressings should increase sugar beet yields in many fields, because tissue tests indicate the need for more nitrogen early enough in the season so that it could be supplied. Side-dressing is a more economical way of supplying nitrogen than applying it all at planting time, because a higher percentage of the nitrogen enters the plant when it is supplied at several times during the growing season. Cook and Millar (2) found that only 41 percent of the nitrogen applied at planting time was recovered by the beet, but where the same amount of nitrogen was applied at three times during the growing season 70 percent of the applied nitrogen was recovered. Another factor which shows that side-dressing with nitrogen may be a desirable practice is brought out by the data of Brown and Irving (1). They show that only 15 percent of the total nitrogen used by a sugar beet is required during the first two months of growth.

While no data are reported here to demonstrate that phosphorus applied as a side-dressing to phosphorus-deficient beets will increase yields, Jones (4) has reported success in the northwest. It has been observed, however, that much of the yellowing or "maturing" of the beet leaves after the middle of September is associated with a low tissue test for phosphorus. It could be that higher planting-time rates or side-dressed fertilizer would correct this situation and be reflected in increased sugar beet yields with a higher content of sugar.

Sugar beets are grown largely on the heavier soils in the state and a small amount of potassium in the planting-time fertilizer is usually sufficient. However, where beet tissue tests were low in potassium, a side-dressing of potassium has increased yields, as is shown in Table 3. These beets showed manganese deficiency symptoms and tissue tests showed the beets to be low in

Figure 1—TISSUE TESTS AS RELATED TO INCREASES IN SUGAR BEET YIELDS RESULTING FROM SIDE-DRESSED NITROGEN



potassium. As a result, the beets were side-dressed. Alternate pairs of rows received manganese sulfate and potassium chloride. Each treatment increased the yields significantly.

It is possible to test green leaves for manganese, but the method requires laboratory facilities. There is no rapid field tissue test for this element. By the process of elimination (by testing for other nutrients), and from symptoms of manganese deficiency which are rather specific and easily distinguished, it is usually possible to avoid the necessity of testing for this element.

The fact that manganese sulfate can be applied successfully as a side-dressing or as a spray is shown in Table 3. Such applications, however, should be considered as emergency treatments, as it is better where it is known that manganese is needed to make the application as manganese sulfate in the planting-time fertilizer.

Boron is another nutrient recommended for sugar beets, although there is no satisfactory tissue test to show when this element is needed. For best results this element should be mixed into the planting-time fertilizer. However, this nutrient can be side-dressed as an emergency treatment with success as is shown in Table 4. Unfortunately it was not possible to obtain yields from this field but stand counts on incidence of heart rot demonstrated clearly the effectiveness of side-dressing with borax. Since the demonstration, that particular farmer always includes borax in his sugar beet fertilizer.

Table 4.—The effect of borax side-dressings on incidence of heart rot[1]

Pounds of Borax per Acre	Number of beets Having heart rot per 500 feet of row
0	37.5
7.5	8.7
15.0	0.0
20.0	1.0

[1] Vader farm—Wisner loam—Side-dressed July 11—Counts were made September 15.

Summary

Rapid plant tissue tests can be made in the field to determine the nutrient status of a plant in regard to nitrogen, phosphorus and potassium. With the aid of these tests it is possible to determine with a reasonable degree of accuracy when a crop could use some supplemental plant food.

Plant tissue tests have been used on sugar beets, and where tests have been "high" throughout the growing season no response to side-dressing was indicated by sugar beet yields. On the other hand, when tissue tests were "low" or "blank" for a specific nutrient, side-dressing with the deficient nutrient has invariably increased sugar beet yields, providing all other growth factors affecting sugar beets were near optimum. Nitrogen, potassium, manganese and boron have been side-dressed to sugar beets and the yields have been increased materially with no consistent decrease in sugar content.

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Effect of Rate and Date of Nitrogen Application on Sugar Beets

J. T. ALEXANDER AND C. E. CORMANY[1]

Tests to study the effects of varying rates and time of nitrogen application on sugar beets were conducted in Colorado, Wyoming and Montana during the summer of 1949.

Procedure

A single test embodying both time and rate of application was conducted at Swink, Colorado, whereas separate tests for each variable were conducted in each of the two other locations—Sheridan, Wyoming, and Sidney, Montana.

Varying dates of nitrogen application were arranged in a Latin square design in the tests conducted at Sidney and Sheridan. Seven treatments, as listed in Table 1, made up the test. Harvested plots were 4 rows wide and 25 feet long. Two 12-beet samples were taken from each plot for sucrose determinations.

Five application rates in the tests conducted at Sidney and Sheridan were arranged in a randomized block of ten replications. Rates are listed in Table 2. Sucrose samples and plot size were the same as in the date-of-application test.

Plots in the Colorado test were 4 rows wide and 53 feet long. The two center rows of each plot were harvested for yield and two 12-beet sugar samples were taken. A split plot design was used and the nine treatments in the test were replicated eight times. The treatments are listed in Table 3.

Results

The time of application in the Colorado test did not influence yield of sugar percent significantly. Nitrogen applied at the rate of 120 lbs. per

Table 1.—Effect of Time of Nitrogen Application on Sugar Beets at Sheridan, Wyoming, and Sidney, Montana, 1949.

	Wyoming Test[1]			Montana Test[2]		
	Sugar per acre	Tons per acre	Percent sucrose	Sugar per acre	Tons per acre	Percent sucrose
Ammonium sulfate side-dressed at planting 300 lbs. per acre[3]	6,336	18.768	16.87	4,448	15.477	14.36
Ammonium sulfate side-dressed at 300 lbs. per acre before:[3]						
1st irrigation	6,602	19.498	16.92	4,717	15.771	14.62
2nd irrigation	6,265	18.641	16.80	4,521	15.753	14.34
3rd irrigation	6,333	19.113	16.57			
4th irrigation	6,201	18.934	16.37			
Split application[4]	6,463	19.128	16.89	4,703	16.119	14.59
Check (no treatment)	6,167	18.314	16.85	4,518	15.421	14.65
General Mean	6,338	18.914	16.75	4,538	15.607	14.47
Sig. Diff.	ns	ns	.35	ns	ns	ns

[1] In the Wyoming test the dates of irrigation were June 20, July 8, July 25 and August 10.
[2] In the Montana test the dates of irrigation were July 18 and August 8.
[3] Ammonium sulfate used was 20.5 per cent nitrogen.
[4] Sheridan applications before 1st and 3rd irrigations. Sidney at planting and before 2nd irrigation.

[1] Associate Agronomist and Chief Agronomist respectively, Holly Sugar Corp.

Table 2.—Effect of Rate of Nitrogen Application on Sugar Beets, Sheridan, Wyoming, and Sidney, Montana, 1949[1]

	Wyoming Test			Montana Test		
	Sugar per acre	Tons per acre	Percent sucrose	Sugar per acre	Tons per acre	Percent sucrose
400 lbs/A of Ammonium sulfate side-dressed[2 3]	6,584	19.201	17.14	4,698	15.818	14.88
300 lbs/A of Ammonium sulfate side-dressed	6,581	19.402	16.96	4,762	15.872	15.01
200 lbs/A of Ammonium sulfate side-dressed	6,285	18.319	17.15	4,472	14.872	15.06
100 lbs/A of Ammonium sulfate side-dressed	6,278	18.194	17.26	4,310	14.728	14.66
Check (no treatment)	6,530	18.922	17.26	4,107	13.788	14.86
General Mean	6,452	18.808	17.15	4,470	15.016	14.90
Sig. Diff.	ns	.831	ns	346	1.138	ns

[1] All plots, including check, received 200 lbs. of treble superphosphate at planting time.
[2] All side-dressings of ammonium sulfate were applied just before the first irrigation.
[3] Ammonium sulfate used was 20.5 per cent nitrogen.

acre, one-half being applied after thinning, mid-June, and the remainder two weeks later, lowered the sugar percent below that obtained when 40 lbs. of nitrogen per acre was applied in a similar application. No significant yield response was observed when the rates of nitrogen application were 40 lbs., 80 lbs., or 120 lbs. per acre.

Fertilizer added to the soil at a rate of 60 lbs. of nitrogen per acre as side-dressing, just previous to a mid-August irrigation, depressed significantly sugar percent in the Wyoming tests. Nitrogen rates of 20 lbs., 40 lbs., 60 lbs., and 80 lbs. per acre failed to influence yield in these tests.

In the Montana tests, varying the time of application of nitrogen fertilizer did not influence significantly the yield of sugar percent of beets. An

Table 3.—Effect of Rate and Date of Nitrogen Application on Sugar Beets at Swink, Colorado, 1949.

Treatment	Sugar per acre	Tons per acre	Percent sucrose
120 lbs/A of Ammonium nitrate[4]			
A[1]	4,353	14.329	15.21
B[2]	5,044	16.013	15.72
C[3]	5,310	17.324	15.26
240 lbs./A of Ammonium nitrate[4]			
A[1]	5,010	16.575	15.05
B[2]	5,008	16.640	15.07
C[3]	5,583	18.192	15.38
360 lbs/A of Ammonium nitrate[4]			
A[1]	5,289	17.692	14.91
B[2]	4,956	16.891	14.68
C[3]	5,240	17.531	14.91
General Mean	5,088	16.799	15.13
Sig. Diff. (19:1) within groups	ns	ns	ns
Sig. Diff. (19:1) between groups	ns	ns	.72

[1] A: side-dressed all 6-15;
[2] B: side-dressed ½ amount 6-15, ½ amount 7-1.
[3] C: side-dressed ⅓ amount 6-15, ⅓ on 7-1, ⅓ on 8-15
[4] Ammonium nitrate used was 33 per cent nitrogen. All side-dressings were followed immediately by an irrigation.

increase in yield was obtained by the application of 40, 60 and 80 lbs. of nitrogen per acre.

Discussion

Results of these tests indicate that the time of application is apt to affect unfavorably the sugar percent of beets, especially when heavy rates of nitrogen are applied late in the season. On the other hand, very little increase in yield was obtained from a split or late fertilizer application over a single early application.

This test illustrates the fact that, because of numerous environmental factors which may be encountered, it is very difficult to anticipate the responses to be obtained by varying rates of nitrogen fertilizer. Factors such as length of growing season, mean temperature and inherent soil fertility all exert important influences on fertilizer response.

Summary

Tests conducted during 1949 in Colorado, Wyoming and Montana indicate, in general, that the time of application did not influence yield and sugar content significantly except for an application as late as August 10.

No significant yield responses were observed in Colorado and Wyoming by increased application up to 120 lbs. and 80 lbs. nitrogen per acre respectively, although the 120 lbs. rate depressed the sucrose slightly. However, in Montana increased yields are noted for 40, 60 and 80 lbs. nitrogen per acre.

No increase in yield was obtained from split application as compared to a single early application.

The Effect of Several Nitrogen Sources On Beet Sugar Yields in Kern County, California[1]

F. J. HILLS AND J. D. AXTELL[2]

Experiments conducted by the University of California in Kern County (7)[3], (6) have indicated that potato yields are increased greatly by the use of nitrogen fertilizers but the increase varies with the type of nitrogen supplied to the plant. In general these trials have concluded that ammonium sulfate or dried blood or a combination of these two nitrogen sources is superior to calcium nitrate, sodium nitrate or uramon when applied in equivalent amounts of nitrogen. In one of these trials the yields from plots fertilized with dried blood and ammonium sulfate exceeded those from plots fertilized with sodium nitrate, calcium nitrate, or uramon by 75 to 175 cwts. of potatoes per acre. Split applications of the nitrate materials had no effect on yields as compared to single applications. This with other data[4] indicates that the yield differences are not due to the leaching of nitrates by the frequent irrigations applied to this crop.

Ulrich (8) conducted pot experiments with sugar beets over a period of six years on the effect of chemical forms of nitrogen on beet sugar production. Metz silty clay loam from the King City area of California was used in these trials. The results indicated no important differences in yield or sucrose concentrations among plants fertilized with anhydrous ammonia, calcium cyanamide, ammonium nitrate, urea, ammonium sulfate, sodium nitrate, or calcium nitrate.

Because of the increase in yields of potatoes from ammoniated fertilizers, a preference by the grower has been shown for this type of nitrogen. This rather marked plant response to ammonia fertilizers has not been reported in other potato growing areas. The question arises: is this condition peculiar to this area or only to this particular crop? The following experiment was designed to study the growth response of the sugar beet to various nitrogen fertilizers in this early potato growing area of California.

METHODS AND PROCEDURES

The field selected for this experiment is located about five miles north of Wasco in Kern County. The soil is Hesperia loam, which is rated as one of the better soils of the area.

It was arbitrarily decided, after considering the field's past history and the general practice in the area, to apply the nitrogenous materials at the

[1] This experiment was conducted by the Spreckels Sugar Co. and the Agricultural Extension Service of Kern County. Assistance was received from Dr. Albert Ulrich of the Division of Plant Nutrition, University of California, Berkeley, Calif., in analyzing the leaf samples. Appreciation is extended to Mr. W. L. Bergen for furnishing the land for this experiment and for his excellent cooperation in its conduct.

[2] Agronomist, Spreckels Sugar Co., and Farm Advisor, Kern county, Calif., respectively.

[3] Figures in parentheses refer to literature cited.

[4] Unpublished data of L. D. Doneen, Division of Irrigation, Univ. of Calif., Davis, Calif.

rate of 100 pounds of nitrogen per acre. Five different nitrogen carriers were selected: ammonium sulfate, ammonium nitrate, uramon, calcium nitrate and sodium nitrate. Phosphate or potassium were not applied as experience in this area had not indicated responses to these nutrients. Subsequent leaf analyses indicated that these elements were not deficient.

The field was planted on February 28, 1948, on single row beds spaced 30 inches apart and was irrigated for germination immediately thereafter. On April 13, when the plants had reached the eight- to ten-leaf stage, they were thinned to approximately one hundred sixty plants per 100 feet of row. A uniform section of the field was selected and the fertilizers applied on April 15 and 16.

The experimental design consisted of a 6x6 Latin square; and five nitrogen carriers plus a machine check (plots not fertilized but subjected to the side dressing action of the applicator) constituted the six treatments. Each plot was eight rows wide and 60 feet long. The fertilizers were applied one row at a time with a Fairbank (2) applicator and banded on each side of the row approximately 5 inches from the plants and 5 inches deep.

Starting May 4, leaf samples were collected at monthly intervals. The petioles of these samples were analyzed for nitrate-nitrogen, phosphate-phosphorus and potassium by the division of plant nutrition of the University of California according to methods developed at that laboratory (10). The leaves selected for analysis were "recently matured leaves" as defined by Ulrich (9). At each sampling date from fifteen to twenty such leaves were taken from the center two or four rows of the center 50 feet of each plot.

The experimental area was irrigated every ten to fourteen days. Judging from the appearance of the plants, soil moisture was adequate except just prior to the second and third irrigations when the plants wilted during the hot part of the day. Thereafter no serious wilting was observed.

On August 11 and 12 the center 50 feet of the four center rows of each plot were harvested by hand. Considerable dry rot canker was present and counts were made to reflect the extent of damage. All readily visible rotted beets were counted as "rotted." Two ten-beet samples were taken from each plot for sucrose and tare determinations.

RESULTS

1. The Effect of the Treatments on Beet Yield and Sucrose Concentrations

A marked response to nitrogen occurred (Table 1). All fertilizer materials increased significantly the tons of beets and gross sugar per acre. Among the nitrogen carriers the yield differences were not significant. None of the treatments differed significantly in sucrose concentration.

2. The Effect of Nitrogen on the Incidence of Dry Rot Canker

Dry rot canker is caused by the organism *Rhizoctonia solani* Kuhn. This organism is also one of the pathogens which causes damping-off of sugar beet seedlings. The fungus is commonly present in many California beet fields and has been reported occasionally to have caused appreciable losses on mature beets in the form of dry rot canker. In at least one other California experiment (12) it has been found that a nitrogen deficiency

favors the incidence of this disease. The same relationship was found by Leach and Davey (5) with southern sclerotium root rot (*Sclerotium rolfsii* Sacc.) In several California field trials they were able to reduce infection through nitrogen applications by 28 to 65 percent over non-fertilized plots.

In this experiment it was observed repeatedly throughout the growing period that more plants were dying from dry rot canker in the check plots than in those which were fertilized. The harvest results (Table 1) support these observations.

All five nitrogen treatments showed significantly lower infections than the non-fertilized areas. This is reflected both in the reduction of the number of beets harvested from the non-fertilized plots and in the lower percentage of infected roots from the plots receiving nitrogen.

Among the nitrogen sources the calcium nitrate and ammonium sulfate treatments had significantly lower amounts of infection than the sodium nitrate treatments. The difference is significant at the one percent level for calcium nitrate and at the five percent level for ammonium sulfate. The infection in uramon and ammonium nitrate plots was intermediate and did not differ significantly from the other nitrogen sources.

The high coefficient of variation for the incidence of this disease indicates the possibility that considerable experimental error may be involved. Additional experiments must be conducted to investigate more intensively this problem before general conclusions can be drawn.

3. Plant Analysis as Related to the Response to Nitrogen

Inspection of Table 2 reveals that all the nitrogen treatments increased significantly the concentrations of nitrate in petioles over that of the check plots from the first sampling date, May 4, until July 19, at which time the same low concentration was reached in petioles from all treatments.

Ulrich (11) has tentatively defined the critical concentration of nitrate nitrogen in such plant material at approximately 1,000 ppm. On this basis a response to nitrogen was indicated by the early date at which the unfertilized plants reached this critical level. Petiole material from plants of all the nitrogen treatments reached this concentration within one or two weeks of each other, indicating that measurable yield differences among these treatments would be unlikely on the basis of differential nitrogen absorption.

4. Differential Concentration of Petiole Nitrates Among the Nitrogen Treatments.

An interesting phase of this experiment are the differences in the concentrations of nitrate in petiole material associated with the nitrogen carriers. On May 4, three weeks after the application of the fertilizers, the plants which were fertilized with calcium nitrate contained significantly higher concentrations of nitrate in their petioles than those which received sodium nitrate or ammonium sulfate. At this date the concentration in plants of the ammonium nitrate treatment was also higher than that of plants fertilized with ammonium sulfate. On May 25 and June 21 the leaf samples show that plants fertilized with calcium nitrate and uramon had higher concentrations of nitrate than those fertilized with any of the other nitrogen

carriers. Petioles from the sodium nitrate treatment contained less nitrate than those from any of the nitrogen treatments while those from ammonium nirate and ammonium sulfate treatments occupied a middle position.

On April 28 and again on May 19 soil samples[5] were taken from two plots of each of the following treatments: calcium nitrate, ammonium sulfate and check. As nearly as possible the samples were taken from the fertilizer bands. Analysis of these samples showed the checks to be low in

Table 1.—Comparison of treatments as to yield, sucrose percent, harvested stand and rotted beets.

Treatment[1]	Tons per Acre		%	Beets	
	Gross Sugar	Beets	Sucrose	Harvested per 100 ft. of Row	Rotted Beets (Percent of Total Harvested)
No nitrogen	3.241	23.38	13.85	148.7	23.2
Sodium nitrate	4.124	28.64	14.38	155.5	16.5
Ammonium sulfate	4.111	29.26	14.05	156.7	9.3
Uramon	4.080	29.71	13.74	154.7	11.8
Calcium nitrate	4.080	28.89	14.16	155.3	8.6
Ammonium nitrate	4.011	28.62	14.04	157.0	12.9
Significant difference[2]	0.245	1.39	N. S.	5.4	5.6[4]
F Value[3]	16.33	24.56	1.01	2.77	8.07
Coefficient of variation	5.3%	4.1%	3.9%	2.9%	34.2%

[1] All fertilizer materials were applied at the rate of 100 pounds of N per acre.
[2] Significant difference is at the 5% level. N. S. means not significant.
[3] Required F value for significance at the 5% and 1% levels are 2.71 and 4.10 respectively.
[4] Required difference for significance at the 1% level is 7.8%.

nitrate at both sampling dates and indicate no important differences in nitrogen (as ammonium plus nitrate) between the two fertilizer treatments. Rapid nitrification is indicated by the disappearance of most of the ammonium in the ammonium sulfate plots by the second sampling date.

Work carried out by others on soils of this area affords data from which it may be postulated that much of this differential absorption of nitrogen might have been associated with the effect of the treatment on water infiltration.

Huberty and Pillsbury (4) in field trials on Hesperia sandy loam near Wasco, Kern county, found that sodium nitrate and also ammonium sulfate (but at a slower and less consistent rate) reduced infiltration as much as 95 percent. Fireman, Magistad and Wilcox (3) in laboratory experiments confirmed these results on this soil and found the same thing on many other western soils. In their experiments sodium nitrate when applied to surface soil in concentrations comparable to 200 to 500 pounds of side dressed material reduced the permeability of Hesperia silt loam 50 percent. They also found that ammonium nitrate and ammonium sulfate reduced permeability but to a lesser extent than sodium nitrate.

In the experiment reported here the sodium nitrate was applied at the rate of 617 pounds per acre side dressed on both sides of the row. The planting was on beds, therefore, water penetrating to the center of the beds had to pass through the fertilizer bands. The nitrate or urea distributed

[5] Dr. L. D. Doneen of the Univ. of Calif., Davis, Calif., kindly assisted in taking these samples and in having them analyzed.

throughout the root zone would be in proportion to the amount of water moving through the fertilizer zones. Any treatment reducing the movement of water in this region would also reduce the distribution of nitrate or urea and likely result in less nitrogen available for absorption. It is assumed that calcium nitrate would tend to aid rather than decrease water infiltration and that appreciable amounts of soluble urea were disbursed throughout the root zones before oxidization to ammoniacal forms.

Table 2.—Comparison of the nitrate-nitrogen concentration in recently matured petioles. Expressed in ppm-dry basis.

Treatments	Sampling dates				
	May 4	May 25	June 21	July 19	Aug. 12[1]
No nitrogen	5,980	360	340	360	375
Calcium nitrate	13,650	10,400	2,630	590	705
Uramon	12,250	10,530	2,220	535	480
Ammonium nitrate	12,720	6,750	1,580	410	530
Ammonium sulfate	10,370	5,730	1,740	410	450
Sodium nitrate	11,270	4,830	1,250	375	290
Significant difference[2]	2,020	1,390	840	N.S.	N.S.
F Value[3]	15.86	65.63	7.82	0.92	1.21

[1] Harvest date—samples taken from buffer rows.
[2] Significant difference is at the 5% level. N. S. means not significant.
[3] Required F values for significance at the 5% and 1% levels are 2.71 and 4.10 respectively.

An attempt was made to detect possible differences in water infiltration. Metal cylinders (1) were pressed into the soil over the fertilizer bands and filled with the same water used to irrigate the field. The infiltration rate was measured by the drop in the level of water over a definite period of time. No differences among the treatments were observed in this manner. Since a surface phenomenon is probably not involved, this method may not be applicable.

DISCUSSION

These results are contrary to those for potatoes in that they indicate large variations in the yield of beet sugar are not likely to be associated with the type of nitrogen carrier used.

Conclusions concerning general or continued use of these fertilizers cannot be drawn from this single experiment. Information is needed as to the effect of these materials when used on other soil types, on the same soil over a period of years, and when they are applied at higher rates.

SUMMARY

1. Five nitrogenous fertilizer materials (ammonium sulfate, ammonium nitrate, calcium nitrate, sodium nitrate and uramon) were applied to sugar beets at the rate of 100 pounds of nitrogen per acre. The plots were arranged in a Latin square. All of the fertilizer materials increased beet yields and sugar production significantly over the check but none affected significantly the sucrose concentration. Among the nitrogen carriers there were no significant differences in beet yields, sugar production, or sucrose concentration.

2. The amount of dry rot canker was appreciably greater in the unfertilized plots.

3. Plant analyses are in agreement with the observed yield responses to nitrogen and also indicate that the plants were supplied adequately with phosphate and potassium.

4. Differences in the concentration of nitrate-nitrogen in petiole material among the plants receiving the various sources of nitrogen were observed. Calcium nitrate and uramon supplied the plants with the highest concentrations of nitrogen. Sodium nitrate supplied less nitrogen than any of the carriers. A reason for this differential absorption of nitrogen is postulated.

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Nitrogen Fertilization of Sugar Beets In the Woodland Area of California

I. Effects upon Glutamic Acid Content, Sucrose Concentration and Yield

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The importance of nitrogen in a fertilizer program for efficient sugar production has been demonstrated in numerous studies on the nutritional requirements of sugar beets. Deficiencies of nitrogen are known to result in low tonnages of beets having high sucrose concentration, while excesses of nitrogen under conditions favorable to growth give high tonnages with beets relatively low in sugar and purity, thereby making sugar recoveries at the refinery more difficult. Evaluation of the nutrient status of the crop has been based usually upon yield and especially sugar data. Occasionally, plant absorption of applied nutrient as determined by leaf petiole analysis has also been taken into account. The present study, made possible by combining the interests of several research groups, includes an additional measurement, that of glutamic acid content of the beet root.

Plant nutrient surveys in California have indicated that the Woodland area of the Sacramento valley is low in nitrogen, although casual tests with this element under field conditions have given both positive and negative results. Alfalfa preceding beets in crop rotation frequently results in a high tonnage of sugar produced and in a high glutamic acid content. In order to obtain a clearer picture of the response to fertilizer in this area, a series of experiments was undertaken cooperatively during 1947 and 1948 by the Spreckels Sugar Company, International Minerals & Chemical Corporation, and the College of Agriculture of the University of California. In this series of 11 fields it was thus possible not only to study the amount of nitrogen required for maximum sugar production, but to observe the relationship of various amount of nitrogen fertilizer to the nitrate concentration of the petioles and to the glutamic acid concentration of the beet roots.

Petiole studies will be reported in the second paper of this series (1)[4]. The effects of nitrogen fertilization on beet and sugar yields and upon sucrose and glutamic acid concentrations at harvest will be considered here. It appears that the glutamic acid might serve as a basis for a rough estimate of the amount of nitrogen available in the soil. Certain differences in the effects of nitrogen upon sugar become apparent when glutamic acid measurements are taken into consideration: it is possible that some changes in sugar concentration have previously been incorrectly ascribed to nitrogen. This must be taken into account in working out a long range program for

[1] International Minerals & Chemical Corporation, Woodland, California
[2] Division Plant Nutrition, University of California, Berkeley
[3] Spreckels Sugar Company, Sacramento, California
[4] Numbers in parentheses refer to literature cited.

predicting accurately the best fertilizer usage for each field. The sugar-glutamic acid relationship is suggested tentatively as a useful indicator of the type of crop giving the most profit to the grower.

Procedure

Six fields were included in the 1947 experiment and five in 1948. All of the fields were located near Woodland. Attempts were made, though not too successfully, to select fields of initial low, medium and high fertility for these studies. The experimental design was a randomized complete block with 8 replications of 5 fertilizer treatments. Ammonium nitrate was applied with a Fairbanks experimental applicator as a side dressing at thinning time. In 1947, treatments of 0 (machine check), 80, 160, 240 pounds of nitrogen per acre, and 240 pounds of N + 200 pounds P_2O_5 (as treble superphosphate) were used. Plots were 6 rows wide and 100 feet long, the center 160 row feet being the harvest area. In 1948, 50, 75, 100, 125, and 175 pounds of nitrogen per acre were applied to plots 8 rows wide and 60 feet long. The harvest area was the center 200 row feet.

The fields studied, the growers who cooperated in each trial, and the dates of planting, application of fertilizer, and harvest are listed in the following summarization:

Field	Grower	Planting Date	Fertilizer Date	Harvest Date
R	Reel, A.	1-26	4-25	8-21-37
M	Moore, A.	2-7	5-6	8-25-47
W	Wilder, W.	3-29	5-14	9-11-47
H	Hass, B. and Ullrich, E.	3-22	5-9	10-20-47
K	Knaggs, J. and Oeste	3-15	5-16	11- 3-47
C	Carlson, H.	4-19	5-23	11-11-47
Ri	Rigney, W.	2-21	4-26	10- 2-48
L	Lowe, K.	1-31	5-1	10-14-48
G	Gill, R.	2-12	5-12	10-27-48
B	Barry, G.	3-10	5-11	11- 9-48
Be	Bender, G.	1-18	4-24	11-11-48

Variety U.S. 15 was used in fields R, L, G, and Be; U.S. 22 in M, Ri, and B; and U.S. 33 in H, W, K, and C. Judging from the appearance of the fields, they were supplied adequately with moisture. Some wilting was noted in fields K and Ri, however.

Sucrose and glutamic acid determinations (2) were made on 40 beet samples taken at random from the harvest areas. Apparent purity determinations were also made on all samples, but are not reported here. Yields were obtained from the weight of all the beets in the harvest area.

Calculations of net return to the grower on the basis of average conditions in the Woodland area were carried out using data on smooth curves passed through the experimental averages. Payments on beets were based on sugar at a net value of $6.50, government benefit included, and values of tops at $0.40 per ton of roots. Average costs per acre were estimated on the basis of $0.12 per pound of nitrogen plus $1.00 for application; net load-

ing and hauling at $0.625 per ton of roots, and harvesting at the usual contract machine harvest rate of $15.00 plus $0.70 per ton of beets.

Discussion

The effects of the various fertilizer treatments upon percent sucrose and glutamic acid, and upon beet and sugar yields, are listed in Tables 1 and 2. The most marked effects of nitrogen fertilizer are on the glutamic acid and sucrose concentrations. Effects on tons of beets, tons of sugar and on crop value can be measured with much less accuracy (note the lower F values), because of the relatively large error in yield measurements.

Table 1.—The Effects of Nitrogen Fertilization upon Sugar Beets Grown in the Woodland, California, Area in 1947.

Field	Treatment Lbs. N/Acre	Per Cent Sucrose	Per Cent Glutamic Acid	Tons Beets per Acre	Tons Sugar per Acre
R	0	17.5	0.08	25.0	4.38
	80	16.9	.14	27.9	4.71
	160	16.1	.17	28.0	4.52
	240	15.5	.22	28.7	4.47
	240+P	15.4	.25	27.8	4.28
	L.S.D. (19:1)	0.5	23%	2.1	(0.40)
	F value	22.4	36.4	4.1	1.4
H	0	18.3	0.07	16.3	2.99
	80	17.7	.12	22.1	3.92
	160	17.3	.16	23.8	4.12
	240	16.3	.22	23.8	3.90
	240+P	16.1	.25	23.9	3.86
	L.S.D. (19:1)	0.5	14%	1.3	0.23
	F value	23.2	137.7	51.2	30.6
W	0	17.3	0.03	5.9	1.03
	80	17.1	.04	13.2	2.26
	160	16.9	.06	17.3	2.93
	240	16.4	.08	19.6	3.22
	240+P	15.8	.09	19.6	3.11
	L.S.D. (19:1)	0.7	32%	3.3	0.60
	F value	5.7	27.9	23.1	17.0
K[1]	0	17.2	0.12	20.0	3.45
	80	17.0	.20	22.8	3.86
	160	15.9	.31	22.3	3.54
	240	15.5	.37	23.3	3.60
	240+P	14.9	.37	22.4	3.36
	L.S.D. (19:1)	0.8	24%	(2.5)	(0.50)
	F value	13.9	41.4	2.1	0.8
M	0	18.0	0.12	20.4	3.66
	80	16.9	.20	23.9	4.01
	160	16.5	.24	26.2	4.30
	240	14.6	.34	27.3	3.99
	240+P	14.5	.35	28.0	4.05
	L.S.D. (19:1)	0.6	13%	1.6	0.30
	F value	53.5	113.8	31.7	4.6
C	60	17.0	0.12	19.3	3.27
	140	16.5	.21	21.7	3.59
	220	16.1	.31	24.8	4.01
	300	15.4	.35	25.4	3.93
	300+P	15.4	.38	24.7	3.80
	L.S.D. (19:1)	0.5	11%	1.9	0.35
	F value	14.1	157.7	16.5	6.0

[1] Nine replications instead of the usual 8.
L.S.D. (19:1) are in parentheses when the F values are not significant.

Glutamic Acid Concentration: Glutamic acid shows a striking response to nitrogen fertilization, a response that is more marked than any other character observed in harvestable beets. The percentage increase is greater, and the chances of the effect being a real one, as measured by the errors involved[5], are considerably better than those for sugar, yield or purity measurements. The average response, judging from the present series of experiments, can be expected to be between a 30 and 70% increase per 100 pounds of

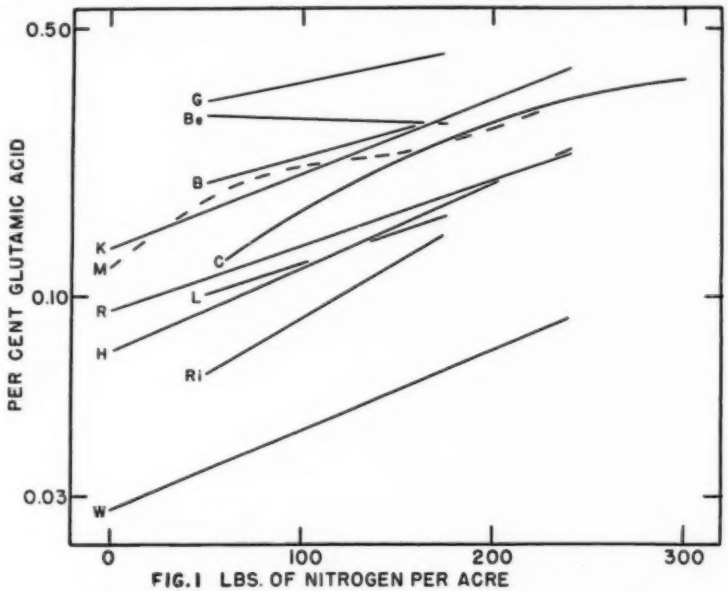

Figure 1. Response of Glutamic Acid to Nitrogen Fertilizer.
Glutamic acid content of beets at harvest time plotted against the amount of fertilizer nitrogen applied as ammonium nitrate at thinning time. Each line depicts the response in a single field in 1947 (240 pound N range) or in 1948 (125 pound N range).

nitrogen applied at thinning time. The actual average increase (between the limits of 50 and 175 pounds of nitrogen per acre) for the 11 fields described was 49% per 100 pounds of N applied. This implies that an unfertilized crop yielding 0.1% glutamic acid would have given 0.149% glutamic acid after fertilization with 100 pounds of nitrogen, if its response had been average; one yielding 0.2% would have given 0.298%.

The significant effect of fertilizer nitrogen upon glutamic acid obtained in all except one field (Be) are shown in Fig. 1. There were wide variations not only in the average glutamic acid concentration (0.05 to 0.37 at 105 pounds of N per acre), but also in the magnitude of the response (from a 4% decrease to a 95% increase). Only two fields, M and C, showed any

[5] See F values in Tables 1 and 2.

significant deviation from a straight line response when glutamic acid was measured on a logarithmic scale[6], and only field C showed a tendency toward decreased response at the higher levels. It may be concluded that the amounts of fertilizer used were far short of those which would be needed to bring glutamic acid to a maximum.

Sugar Concentration: All fields except Be showed regular decreases in percent sugar with increasing nitrogen, although the results were not so highly significant as the glutamic acid increases. The decrease in sugar in most cases tended to accelerate at higher fertilizer levels. The only indication that a minimum sugar concentration was being approached was in the very unusual field, Be.

Tonnage of Beets: Yield of roots showed significant changes in only 6 of the fields (R, M, W, H, C, and Ri), and covered a wide range of possible responses from a straight line increase in field Ri to a probable decrease in G. The only fields in which plant population had a significant effect on the results were C, K, and W. Field C showed considerable difference in harvestable stand due to loss of beets during cultivation. Values reported for yield of beets and sugar have been equalized to the average stand. Field K contained 12 plots in which the border rows on one side were destroyed. The resulting loss of competition caused an average increase of 4.7 tons per acre. Values reported for tonnage of beets and sugar are estimates of the average tonnage after removal of this source of bias.

In field W, there were enormous differences in tonnage resulting from disease conditions which were corrected partially by the application of nitrogen fertilizer. Identification of the diseases present and counts of the "unmarketable" and "still marketable" infected beets were made by Dr. L. D. Leach[7]. Beets designated as "unmarketable" were those in which the infection had progressed to such an extent that they would not have been picked up during hand harvest. Three diseases were present: wet root rot *(Phytophythora drechsleri* or *Pythium aphanidermatum)*, southern sclerotium root-rot *(Sclerotium rolfsii)*, and dry-rot canker *(Rhizoctonia solani)*. Wet root rot, which infected 4.2% of the beets and is predisposed by excessive soil moisture, was unaltered by fertilization. Data on sclerotium root-rot and dry-rot canker are given in the following summarization:

Infection	Treatment—Pounds of N per Acre				
	0	80	160	240	240+P
	Per Cent of Total Beets Infected				
So. Sclerotium Root-Rot					
Unmarketable	14.0	11.5	4.7	3.3	1.9
Still marketable	3.7	4.5	3.7	2.3	1.5
Dry Rot Canker					
Unmarketable	8.6	4.6	2.6	1.2	1.6
Still marketable	4.4	6.4	7.4	7.8	5.2
Missing at Harvest	22.0	3.6	-----	-----	-----

Percents are based on estimates of the total original population.

The beets missing at harvest were obtained by comparing thinned stands with the number of beets at harvest. It appeared that 22% had disappeared

[6] The reasons for the use of logarithms are discussed in a paper reported previously (2).
[7] Plant Pathologist, California Agricultural Experiment Station, Davis, California.

in the unfertilized plots prior to harvest, whereas practically all of the beets in the 160 and 240 treatments could be accounted for at harvest.

The increase in the number of marketable beets by nitrogen fertilization was very significant; the effect of phosphorus at the high N level was not. The action of the fertilizer appears to be somewhat different in the two diseases. With southern sclerotium rot, the incidence of infection was reduced with each increase of nitrogen applied, as previously established by Leach (3). Here the "still marketable" beets probably represent recent infections. In the case of dry rot canker, the total number of infected beets was nearly as large in the fertilized as in the unfertilized treatments, but the percentage of unmarketable beets was reduced strikingly by nitrogen application. In the heavily fertilized treatments most of the infections were arrested and the beets were still acceptable. Susceptibility to both infections became marked at a level of nitrogen fertility corresponding to a glutamic acid content of about 0.05%.

Table 2.—The Effects of Nitrogen Fertilization upon Sugar Beets Grown in the Woodland, California, Area in 1948.

Field	Treatment Lbs. N/Acre	Per Cent Sucrose	Per Cent Glutamic Acid	Tons Beets per Acre	Tons Sugar per Acre
Ri	50	16.5	0.06	17.4	2.88
	75	16.3	.08	18.5	3.01
	100	15.9	.09	18.8	3.00
	125	15.8	.10	20.7	3.27
	175	15.3	.15	23.0	3.56
	L.S.D. (19:1)	0.6	23%	2.1	0.35
	F value	5.1	19.4	9.5	4.5
G	50	15.7	0.32	32.2	5.05
	75	15.2	.35	32.1	4.88
	100	15.2	.36	32.0	4.87
	125	15.1	.38	31.7	4.77
	175	14.7	.43	30.9	4.53
	L.S.D. (19:1)	(0.8)	(22%)	(1.1)	(0.35)
	F value	1.4	2.2	2.0	2.5
B	50	15.5	0.20	31.3	4.84
	75	15.5	.21	30.6	4.72
	100	15.0	.23	32.0	4.80
	125	15.0	.25	30.8	4.60
	175	14.0	.30	31.5	4.43
	L.S.D. (19:1)	0.5	14%	(1.7)	(0.32)
	F value	11.8	11.5	0.9	2.2
L[1]	50	14.9	0.09	24.6	3.67
	75	14.7	.12	24.7	3.64
	100	14.3	.12	24.4	3.50
	125	14.2	.14	24.1	3.42
	175	13.3	.15	24.8	3.30
	L.S.D. (19:1)	0.6	21%	(1.1)	0.21
	F value	10.5	8.5	0.5	4.7
Be	50	13.2	0.29	30.9	4.07
	75	12.7	.31	31.9	4.05
	100	12.6	.31	31.5	3.96
	125	12.4	.26	30.3	3.76
	175	12.6	.29	30.7	3.84
	L.S.D. (19:1)	(0.8)	(14%)	(1.4)	(0.26)
	F value	1.0	2.7	1.8	2.2

[1] Only 7 replications instead of 8.
L.S.D. (19:1) are in parentheses when the F values are not significant.

Tons of Sugar per Acre: Five fields (R, M, H, K, C) showed maximum values for yield of sugar, though in two of these (R, K) the changes were not large enough to be significant. All five occurred in the 1947 experiments, which illustrates the value of using unfertilized controls and a range of at least 240 pounds of nitrogen per acre in such experiments. Three (R, Ri, L) of the remaining 6 fields gave significant differences. Tests carried out on the unfertilized border area of field L indicated the probability of a sharp optimum at 50 pounds of nitrogen per acre.

Table 3.—The Estimated Fertilizer Level for Maximum Return to the Grower and the Per Cent Sucrose and Glutamic Acid of the Corresponding Crop.

Field	Pounds N/Acre	% Sucrose	% Glutamic Acid
H	120	17.5	0.13
K	70	17.0	.19
R	60	17.0	.12
M	110	16.9	.21
C	210	16.1	.30
G	50	15.7	.32
B	50	15.5	.20
W	240	16.2	.09
Ri	175	15.3	.15
Y	95	15.5	.13
L	50	14.7	.09

Crop Value: Calculations of net return from fertilizer applied were used to obtain estimates of the optimum level of nitrogen usage for the grower. The same procedure was applied to the field at Yolo, California, (Y) previously described (2). These estimates are shown in the first column of Table 3. They average around 120 pounds of nitrogen per acre, but the spread of values from field to field is so great that the average fertilizer requirement for the area cannot be estimated with any precision from these data. It might also be concluded that use of an average fertilizer requirement for the area, even if known accurately, could result in fairly frequent losses to the grower of as much as $50 per acre through missing the actual optimum for his particular field.

Obviously much of the difference in nitrogen requirement was caused by differences in fertility before the application of fertilizer. Accordingly, it was hoped that the glutamic acid or sugar content, both changing rapidly with nitrogen supply, would give a measure of the quality of the crop giving the optimum return to the grower. Sugars and glutamic acids expected at the optimum N level for each field were estimated from smooth curves through the original data. These are also shown in Table 3. On the average, the results center at about 16.2% sucrose and 0.20% glutamic acid for the most profitable crop. Here again, the range of results is disappointingly large, from 14.7 to 17.4% for sugar and 0.09 to 0.3% for glutamic acid.

Much of this variation may be explained by a consideration of the relationship between sugar and glutamic acid in beets. This is shown in Fig. 2 where the lines represent the change in sugar and glutamic acid produced by varying amounts of nitrogen fertilizer. The crops responded generally in a similar fashion, the curves being nearly parallel, but there are highly significant differences in the relative positions of the curves for the various fields. The data fall into three sharply distinguished groups which

may be characterized by the sugar obtained when fertilizer produced a glutamic acid concentration of 0.1%. The major group of seven fields has a sugar of about 17.6% at 0.1% glutamic acid: the second group, 16.0% sugar; and the lowest field (L), 14.7%. The fields seemed to maintain this difference at all levels of glutamic acid.

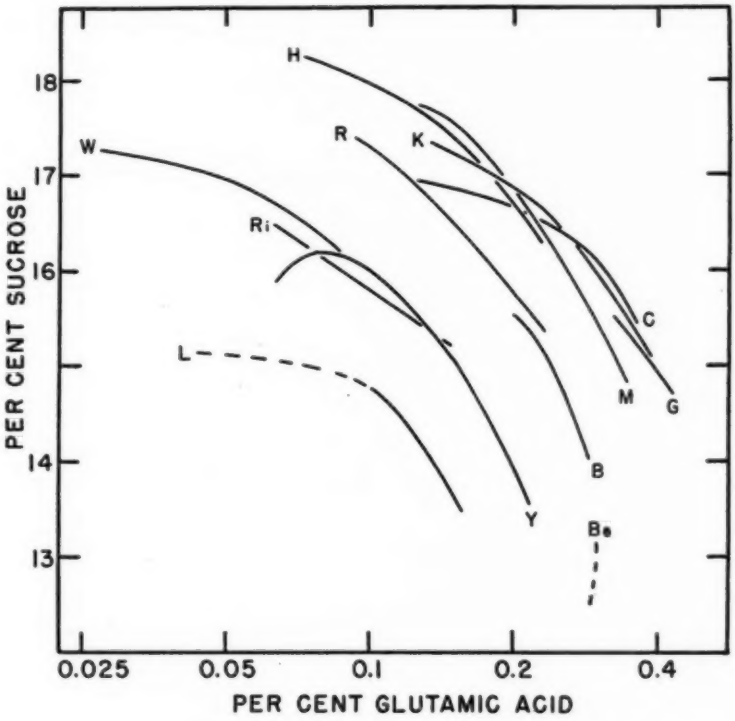

Figure 2. Changes in Sugar and Glutamic Acid Produced by Varying Amounts of Nitrogen Fertilizer.

Lines depict the fall in sugar and the increase in glutamic acid in various fields as fertilizer nitrogen is increased.

All fields tended to produce the optimum crop near the shoulder of these curves; best crops were never obtained with too low sugar or too low glutamic acid. The three groups gave optimum return from fertilizer at the following average values:

Group		% Sucrose	% Glutamic Acid
I	(H, K, R, M, C, G, B)	16.8	0.19
II	(W, Ri, Y)	15.7	0.12
III	(L)	14.8	0.09

The stratification of fields on the basis of both sugar and glutamic acid appears to improve greatly the accuracy of estimates of the best fertilizer usage. Thus, the larger group varies only from 16.1 to 17.5% in sucrose concentration producing the best crop. Inaccuracy in yield data and need for further stratification probably account for much of the remaining error.

The tendency for the optimum sugar to increase as the optimum glutamic acid increases is probably a continuous change, the three groups noted in these experiments being due to chance field selection. The magnitude of the increase in sugar is such that the purity would be higher in the higher sugar fields, other things being the same.

There is little evidence in the data as to possible causes of the differences between the three groups. Soil nitrogen has no possible connection. Seed variety or the amount of irrigation had no apparent effect. There is a slight tendency, probably not significant, for the higher sugar fields to show higher tonnage, and for them to have an optimum tonnage more closely approaching the maximum obtainable with increasing nitrogen.

The only factor known to affect the sugar-glutamic acid relationship is that of age of beet (2). The rate of change of sugar during the harvest season is such that it can explain only a small part of the differences between fields noted. It seems probable that environmental factors (such as stage of growth during thinning operations, minor elements, etc.) regulating speed of early growth may be important.

A general picture of the changes described may be obtained from the concept of both sugar and glutamine (precursor of glutamic acid) as storage compounds. Factors producing good storage conditions, such as slow growth rate prior to harvest, tend to raise the concentration of both compounds, and may be grouped together as the *storage potential* of the crop. Soil nitrogen affects the two compounds in the opposite direction, but in very similar fashion. Sugar at harvest is determined by the storage potential less the nitrogen effect, and glutamic acid by the storage potential plus the nitrogen effect (in this case nitrogen is relatively more important). The sum of the two measurements, taken in proper proportion, eliminates the large nitrogen effect altogether, and gives a quantity proportional to the storage potential of the crop.

The findings help to explain why early nitrogen determinations have been of such little value in predicting best nitrogen fertilizer levels, since the manner of utilizing the nitrogen varies so much from field to field. Fields with a high storage potential will require more nitrogen to reach their most profitable crop.

Summary

Glutamic acid undergoes a geometric increase with nitrogen fertilizer averaging 49% increase per 100 pounds of nitrogen per acre. Actual glutamic acid values varied from 0.03 to 0.44% in different fields at different fertilizer levels. The response of glutamic acid to nitrogen bears a striking correlation to that of sugar, though in the opposite direction. Fields at the same glutamic acid concentration show significant differences in the amount

of sugar present. Those with relatively high sugar at a given glutamic acid level maintain their relative advantage in sugar as fertilizer is increased. This new relationship may be useful in distinguishing between fields with too much nitrogen and those low in sugar for other reasons.

The best crop of beets, from the grower's standpoint, is the one produced with that amount of nitrogen resulting in the highest net return. From the average of these experiments, the best crop in the Woodland area contains about 16.2% sugar. This figure varies from field to field with the capacity to store up nitrogen, being 16.8% in beets containing 0.19% glutamic acid and 14.8% in beets of 0.09% glutamic acid.

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Nitrogen Fertilization of Sugar Beets In the Woodland Area of California[1]

II. Effects upon the nitrate-nitrogen of petioles and its relationship to sugar production

ALBERT ULRICH[2]

The importance of nitrogen in the fertilizer program for the production of sugar beets in the Woodland area has been indicated by several plant nutrient surveys (3)[3]. Trials with nitrogen in this area have given both positive and negative results. Failure to obtain increases in yield from the application of nitrogen on deficient fields were believed to be related to the use of insufficient amounts of nitrogen, to an incorrect placement of the materials or to faulty timing of the fertilizations; whereas in fertile fields the supply of nitrogen was already adequate for the needs of the crop. A unique opportunity for testing these ideas arose in a series of field experiments conducted in 1947 (7). These experiments were designed to study the effect of nitrogen and phosphorus fertilization on the growth and development of sugar beet plants in 7 different fields varying in crop-producing power and, as will be shown later, in nitrogen nutrition. Through the use of petiole analyses, it was possible to follow the changes taking place in the nitrogen status of the beets and to relate these observations to sugar concentrations, to beet yields, to sugar production and to efficient nitrogen fertilizations. It is the purpose of this paper to report these findings.

Reference in this paper will be made from time to time to the critical nutrient concentration of sugar beets. The theoretical basis for this concept and its relationship to beet growth has been reported elsewhere (4, 6). Briefly, the critical concentration is that narrow range of concentrations for a given nutrient at which growth is first retarded in comparison to plants with higher concentrations of the same nutrient.

Procedure

The procedures employed in the present experiments, except for the petiole analyses, have been given in the previous paper of this series (7). The plant samples in all fields except Y consisted of 20 petioles which were collected from each plot at 2-week intervals from the time the beets were fertilized until they were harvested. The first petiole for the sample, blade

[1] During the course of these experiments assistance was received from the personnel of the International Minerals and Chemical Corporation, the California Packing Corporation and the Spreckels Sugar Company. In addition to this aid, the International Minerals and Chemical Corporation furnished the fertilizers for the experiments and supplied funds for the analysis of the petioles for nitrate and the beets for sugar. The cooperation received from these sources is gratefully acknowledged.

[2] Associate Plant Physiologist, Division of Plant Nutrition, University of California, Berkeley 4, California.

[3] Numbers in parentheses refer to literature cited.

discarded, was taken from a recently "matured" leaf (4) from a beet in the 2 center rows of the plot after walking into the plot 2.5 feet. Thereafter a petiole was taken every 5 feet alternating from row to row until 20 petioles had been collected. In field Y (6) the petiole samples were collected by walking 30 feet into the plot and taking 4 petioles from the center 4 rows. Thereafter 4 more petioles were taken every 60 feet until a total of 40 petioles had been collected at 10 separate stations within each plot. The samples from all locations were received at Berkeley, California, within 24 to 48 hours after their collection and upon their arrival were cut into sections from 2 to 5 millimeters in length. A 50- or 100-gram sample of each was dried in an oven at 70 degrees C., ground in a Wiley mill to pass a 40-mesh sieve and then analyzed for nitrate-nitrogen, phosphate-phosphorus and potassium (5).

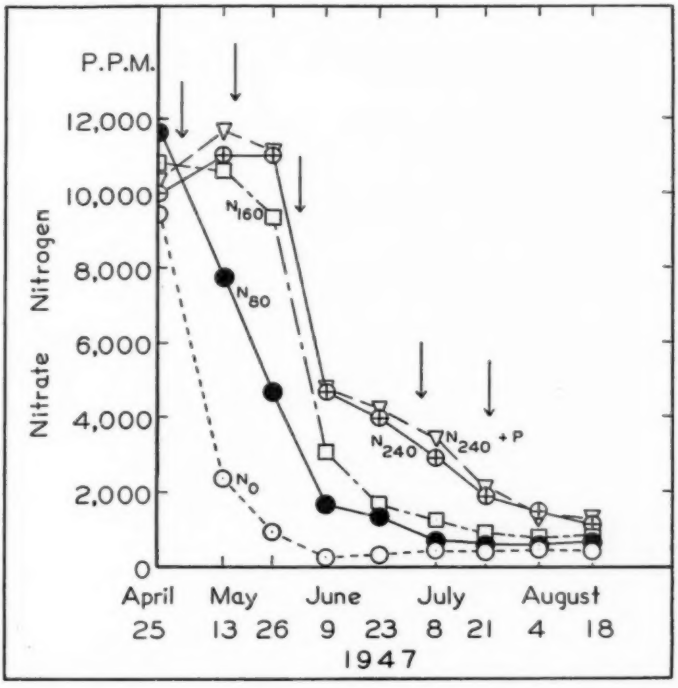

Figure 1. Nitrate-nitrogen (dry basis) of recently "matured" petioles for field R (Yolo fine sandy loam) as related to the amount of nitrogen applied and date of leaf sampling. N = pounds of nitrogen per acre applied as ammonium nitrate in the amounts indicated by the numbers in the subscripts thereto and P = 200 pounds per acre of P_2O_5 added to the soil as treble super phosphate. The arrows indicate the dates of irrigation subsequent to the fertilization of April 25, 1947.

Experimental Results

Field R.—The results of the nitrate-nitrogen analyses of the petioles collected at 2-week intervals from field R are presented in Figure 1. Fertilizer applied to this field on April 25, 1947, became effective shortly after the irrigation of May 1. Prior to fertilization, the nitrate-nitrogen values of the means for the proposed treatments varied from 9,600 to 10,800 parts per million, and as expected, none of these differences were statistically significant.

On the next sampling date, May 13, the plants fertilized with more than 160 pounds of nitrogen per acre did not decrease in nitrate-nitrogen concentration, whereas those fertilized with 80 pounds of nitrogen or less decreased sharply. These differences in nitrate-nitrogen concentration of the petioles taken from the fertilized and unfertilized plots indicate that the nitrogen applied to the soil had been absorbed readily by the beets and had accumulated to a relatively high concentration within the plant.

On the next sampling date, May 26, the nitrate concentrations of the petioles from the plots treated with 160 pounds of nitrogen or more were still at a high nitrate level, whereas further decreases took place for the beets fertilized with 80 pounds of nitrogen and for the unfertilized beets. On subsequent samplings the petioles of the untreated beets contained less than the critical nitrate-nitrogen concentration of 1,000 parts per million (6) and remained at this low level until the beets were harvested on August 18. The petioles of the beets fertilized with 80 pounds of nitrogen also decreased in concentration gradually, and after July 1 remained below 1,000 parts per million. The petioles of the beets fertilized with 160 pounds of nitrogen stayed above the critical concentration until July 17, whereas those fertilized with 240 pounds of nitrogen remained above this level until harvested.

The beet yields from field R, given in Figure 2 and in Table 1 (7), were in accord with the results of the petiole analyses. Beets with the lowest nitrate-nitrogen concentration produced the lowest yield and the highest sugar concentration. A significant increase in beet yield was observed only for the 80-pound nitrogen treatment, and thereafter more nitrogen failed to increase the yields. Sugar concentrations, in contrast to beet yields, were

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Figure 2 (see page 375). Summary of results for seven fertilizer experiments conducted with sugar beets on fields R (Reel), M (Moore), Y (Pockman), W (Wilder), H (Hass and Ullrich), C (Carlson) and K (Knaggs and Oeste). Each horizontal line begins with the date of planting and ends with the harvest. The broken line to the left indicates the period when the beets were in the seedling stage and not sampled; the solid line, the period when the petioles were above 1,000 parts per million of nitrate-nitrogen; and the broken line to the right, the period below 1,000 parts per million of nitrate nitrogen. The numbers above the broken line to the right indicate the days duration of nitrogen deficiency. The arrow upwards indicates the thinning date; the vertical bar to the right of the arrow, the date of fertilization; and the arrows downward, the dates of irrigation. L.S.D. equals least significant difference at the 5% level and n.s. indicates the differences noted were not statistically significant. N = nitrogen derived from ammonium, with the exception of 60 pounds from ammonia in field C. P = 200 pounds P_2O_5 per acre derived from treble super phosphate.

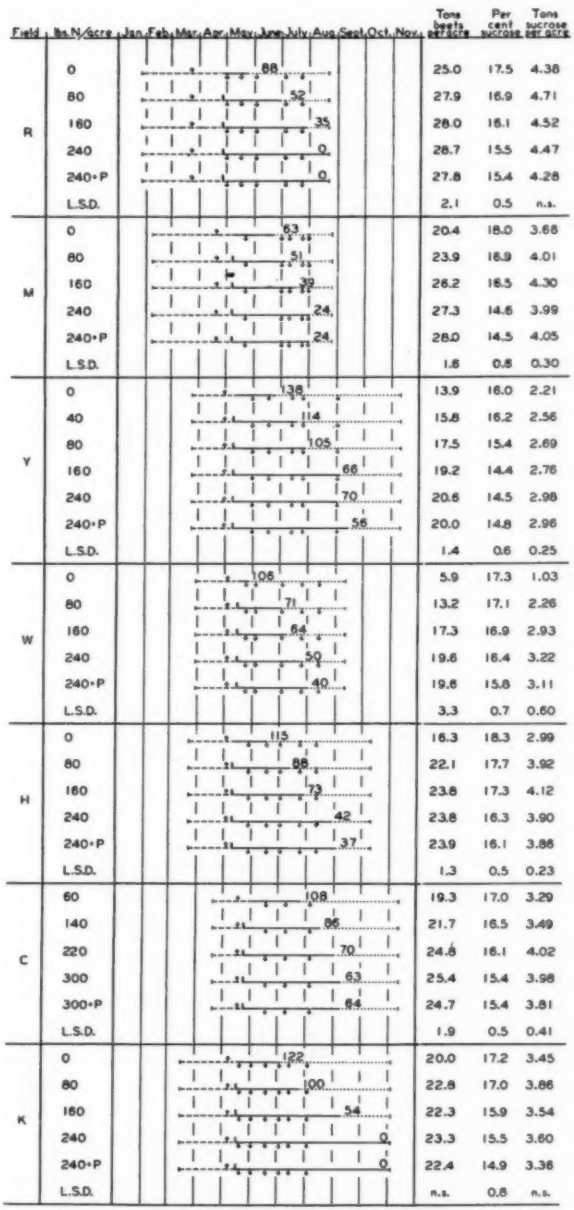
Field
lbs N/acre
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov.
Tons beets per acre
Per cent sucrose
Tons sucrose per acre
R
0 88 25.0 17.5 4.38
80 52 27.9 16.9 4.71
160 35 28.0 16.1 4.52
240 0 28.7 15.5 4.47
240+P 0 27.8 15.4 4.28
L.S.D. 2.1 0.5 n.s.
M
0 63 20.4 18.0 3.66
80 51 23.9 16.9 4.01
160 32 26.2 16.5 4.30
240 24 27.3 14.6 3.99
240+P 24 28.0 14.5 4.05
L.S.D. 1.8 0.8 0.30
Y
0 138 13.9 16.0 2.21
40 114 15.8 16.2 2.56
80 105 17.5 15.4 2.69
160 66 19.2 14.4 2.76
240 70 20.6 14.5 2.98
240+P 56 20.0 14.8 2.96
L.S.D. 1.4 0.6 0.25
W
0 106 5.9 17.3 1.03
80 71 13.2 17.1 2.26
160 64 17.3 16.9 2.93
240 50 19.6 16.4 3.22
240+P 40 19.8 15.8 3.11
L.S.D. 3.3 0.7 0.60
H
0 115 16.3 18.3 2.99
80 88 22.1 17.7 3.92
160 73 23.8 17.3 4.12
240 42 23.8 16.3 3.90
240+P 37 23.9 16.1 3.88
L.S.D. 1.3 0.5 0.23
C
60 108 19.3 17.0 3.29
140 96 21.7 16.5 3.49
220 70 24.8 16.1 4.02
300 63 25.4 15.4 3.98
300+P 64 24.7 15.4 3.81
L.S.D. 1.9 0.5 0.41
K
0 122 20.0 17.2 3.45
80 100 22.8 17.0 3.86
160 54 22.3 15.9 3.54
240 0 23.3 15.5 3.60
240+P 0 22.4 14.9 3.36
L.S.D. n.s. 0.8 n.s.

Figure 2.

highest for beets from the untreated plots and thereafter decreased in concentration with each increment of nitrogen. The net effect was no significant change in sucrose production because the decreases in sucrose concentration cancelled the increases in yield.

Further inspection of the petiole analyses (Figure 1) indicates that fertilizer should be applied on this field so as to be available to the beets by the first part of May. Prior to May, the beets were well above the critical concentration and accordingly were supplied adequately with nitrogen. On the basis of the petiole analyses alone, the fertilized beets should have been allowed to grow longer than August 18 in order to permit a maximum accumulation of sugar. Unless the growing period is extended, the results of the petiole analysis suggest that approximately 80 pounds of nitrogen per acre would be satisfactory for this field. Through systematic petiole sampling, adjustments in the amount of nitrogen applied to this field could be made either during the current season or in succeeding crops, thereby utilizing nitrogen more effectively in the production of sugar by the beets.

Field M.—The results of the petiole analyses for field M are presented in Figure 3. Fertilizer was applied on May 6 and the field was irrigated for the first time thereafter on May 21. On May 5, which was prior to fertilization, the beets had a very high nitrate concentration. On May 20, which preceded the first irrigation, the nitrate-nitrogen concentration of the petioles had decreased considerably but was still above 5,000 parts per million for beets of all treatments. None of the differences occurring on May 5 and May 20 were statistically significant. On the first sampling after irrigation there were large increases in nitrate-nitrogen concentration of the fertilized beets.

These increases were in accord with the amount of nitrogen applied, with the lowest increase for the 80-pound application and the highest for the 240-pound application. As in field R, the nitrate-nitrogen concentrations of the petioles from the untreated plots decreased sharply, being slightly above 2,000 parts per million on June 2 as contrasted with figures of 10,000 or more for the fertilized beets. On June 17 the nitrate-nitrogen concentrations of the petioles of all beets decreased precipitously. Further decreases occurred on July 7, with the petioles for the untreated and the 80-pound-nitrogen-treated plots being below 1,000 parts per million. The petioles for the other treatments were still above this critical concentration. On July 28 the nitrate-nitrogen concentrations of the petioles decreased still more for all nitrogen-treated plots, and finally on August 11 the petioles from all plots were well below the critical nitrogen concentration.

The beet yields given in Figure 2 again confirm the indications of the plant analyses. The lowest yields were obtained from the untreated plots and a significant increase in yield took place for the plots treated with 80 pounds of nitrogen. When more nitrogen was added to the soil, further increases in yield over the 80-pound application took place which were significantly greater for the 240-pound application, but not for the 160-pound application. Again the sucrose concentrations decreased with the nitrogen applications. These decreases in sucrose concentration were more than offset by the yield increases, and the net effect was an increase in sugar production.

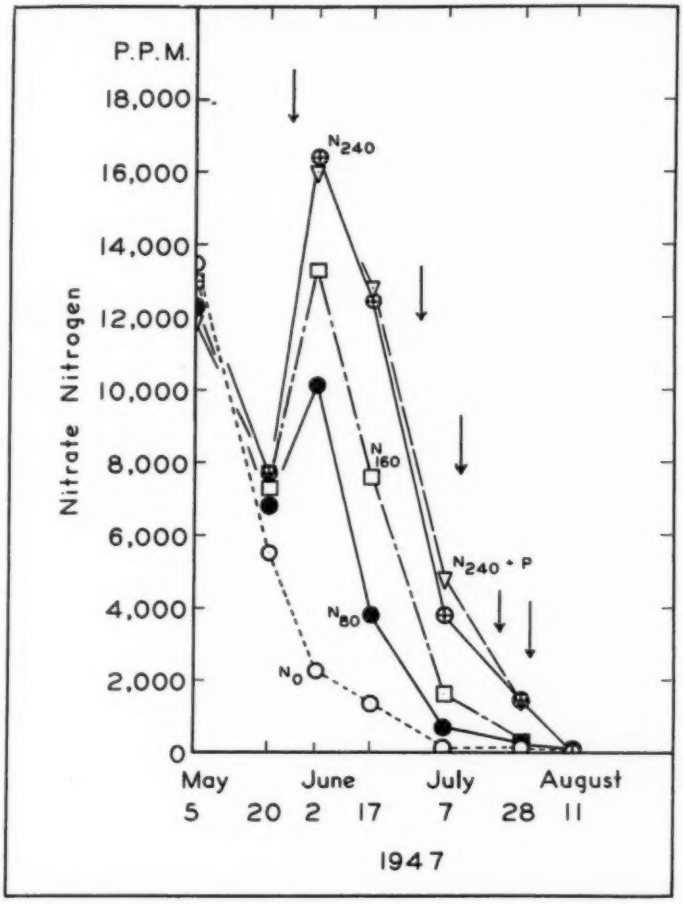

Figure 3. Nitrate-nitrogen (dry basis) of recently "matured" petioles for field M (Sacramento fine sandy loam) as related to the amount of nitrogen applied and date of leaf sampling. N = pounds of nitrogen per acre applied as ammonium nitrate in the amounts indicated by the numbers in the subscripts thereto and P = 200 pounds per acre of P_2O_5 added to the soil as treble super phosphate. The arrows indicate the dates of irrigation subsequent to the fertilization of May 6.

The plant analyses indicate that when beets are planted on this field in February nitrogen may be added as late as the latter part of May without impairing the nitrogen levels of unfertilized beets. Again, as in field R, a delay in harvesting might have resulted in greater sugar production because the beets receiving the highest amount of nitrogen were not deficient in nitrogen long enough to result in maximum root development and sugar storage.

Field Y.—In contrast to the fields which had relatively high yields for the untreated plots and a relatively high nitrogen status during the growing season, other fields had very low yields from the untreated plots (figure 2). The beets in field Y were fertilized on May 7 and 8 and irrigated on May 30. Analyses of the first petiole samples, taken on June 10, represent the condition of the beets after the fertilizer became effective (Figure 4). The nitrate concentrations of these petioles again reflected the fertilizer treatments, being lowest for the untreated plots, intermediate for the 40- and 80-pound treatments and highest for the 160- and 240-pound treatments. By the second sampling date, June 24, the nitrate-nitrogen values had decreased rapidly in approximately the same proportion for all treatments, with the petioles of the untreated plots being at the critical concentration of 1,000 parts per million. Thereafter the values for the petioles from the untreated plots were well below this level. The petioles of the other plots, 40-pound, 80-pound, 160-pound, 240-pound and 240 + P, decreased to the critical concentration on July 19, July 28, September 1, September 5 and September 15, respectively.

The beet yields obtained from this field (Figure 4) again confirm the results of the petiole analyses, and just as in fields R and M, the nitrogen treatments resulted in decreases in sugar concentration. These decreases in sucrose concentration were unexpected because, judging from the results of pot experiments conducted at Berkeley (2), the beets had been below the critical nitrogen level long enough to restore their sugar concentration. Since similar decreases in sugar concentration were observed in other fields of comparable nitrogen starvation periods, this discrepancy between the results of pot and field experiments should be reviewed critically.

According to results of the beet and sugar yield (Figure 2) and the petiole analyses (Figure 4), more nitrogen appears to be desirable on field Y. In addition to the nitrogen deficiency, the phosphate analyses of the petioles indicate that phosphorus should be considered in the nitrogen program: the beets were low in phosphate-phosphorus and the phosphorus added as fertilizer to the soil had not been absorbed by the plants. Potassium was found ample in this field at all times. (Phosphorus and potassium analyses not reported here).

Field W.—The results for field W (Figures 2 and 5) are similar to those observed for field Y. The beets were also planted relatively late in the season and likewise gave very low yields at the time of harvest on September 3. The field was fertilized on May 14 and irrigated shortly thereafter. Analyses of the petiole samples taken on May 14, just before fertilization, showed that the beets from all plots were well supplied with nitrogen

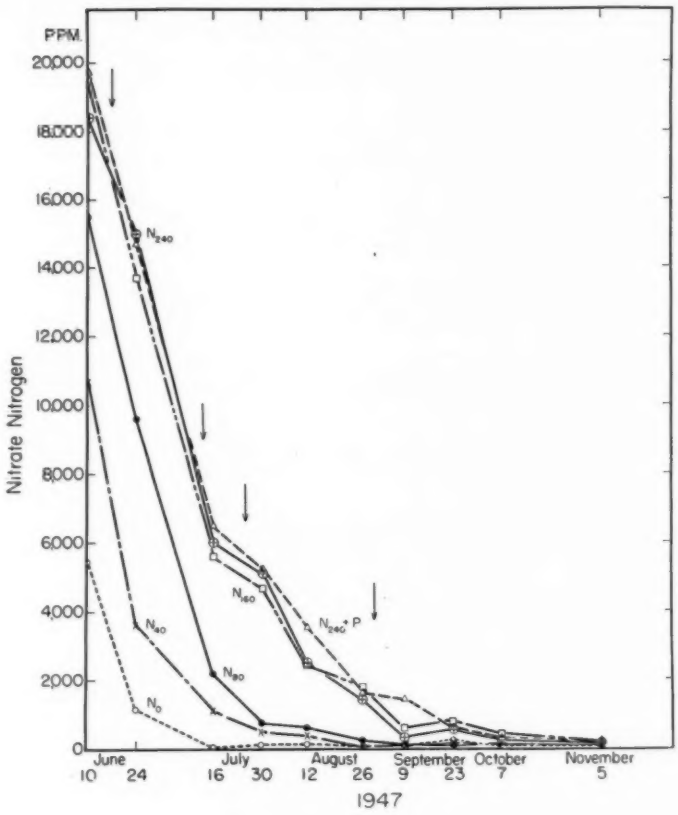

Figure 4. Nitrate-nitrogen (dry basis) of recently "matured" petioles for field Y (Sorrento clay loam) as related to the amount of nitrogen applied and date of leaf sampling. N = pounds of nitrogen per acre applied as ammonium nitrate in the amounts indicated by the numbers in the subscripts thereto and P = 200 pounds per acre of P_2O_5 added to the soil as treble super phosphate. The arrows indicate the dates of irrigation subsequent to the fertilization of May 7 and 8 and the irrigation of May 30.

(Figure 5). On May 28, the first sampling after irrigation, there were large differences in the nitrate content of the petioles. On this date, the petioles from the untreated plots were at the critical concentration whereas those from all nitrogen-treated plots increased in nitrate-nitrogen concentration to about 10,000 parts per million, except the petioles from the plots treated with 80 pounds of nitrogen, which contained about 7,000 parts per million. Decreases in nitrate-nitrogen concentration took place rapidly for subsequent petiole samplings for the 80, 160, 240 and 240 + P treatments, and these declined to the critical concentration on July 2, July 9, July 23 and August 2, respectively.

An important factor associated with the low beet yields from the untreated plots in field W was the damage caused by root rot. The percentage of beets damaged in the untreated plots was significantly higher than in the plots treated with nitrogen (7). The petioles which comprised the samples from these plots were taken from beet plants which had survived the root rot attack or had not yet succumbed to it. The nitrate-nitrogen concentration in these petioles reflected the amount of nitrogen which the beets could get from the soil and that which was not used in growth.

The nitrogen present in the beets which died, however, was not available, or at least not readily available, to the living beets; consequently, the rotted beets did not contribute greatly to the harvest yields nor to the nitrogen supply of the living beets. Accordingly, the nitrate-nitrogen concentration of the petioles for the untreated beets reflected largely the condition which would have existed in the beets without the presence of root rot. Since the untreated beets were deficient in nitrogen relatively early in the growing season, and since an increase in beet yield was observed in other comparable fields of this investigation, it is safe to assume that smaller increases in yield would have occurred on this field had root rot not been present. Clearer confirmation between the results of the petiole analyses and the beet yields was obtained, however, for the 80- and 160-pound nitrogen applications. Root rot damage for these two treatments was slight but the yields still differed significantly, thus confirming again the results of the petiole analyses.

The sugar percentages for field W were, on the average, one unit greater than for field Y. Since both fields were planted to the same variety (U. S. No. 33) at approximately the same time and were located in the same climatic zone, the difference in the sugar percentages of the two fields could be attributed either to harvesting the beets earlier in field W or to some inherent difference in the soils of the two locations.

In field W, just as in field Y, results of the petiole analyses indicate that more than 80 pounds of nitrogen could be used safely in meeting the nitrogen requirements of beets on this field. In both instances nitrogen fertilization might be delayed up to the time of thinning or shortly thereafter. Further study of this point, particularly a comparison of nitrogen applied at planting time with nitrogen applied at the time of thinning, would be of interest in these fields of low nitrogen content.

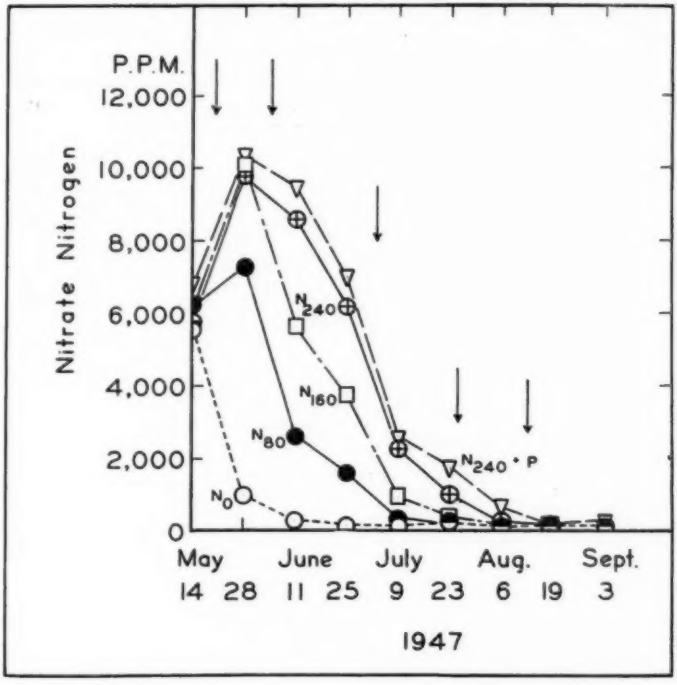

Figure 5. Nitrate-nitrogen (dry basis) of recently "matured" petioles for field W (Sacramento clay loam) as related to the amount of nitrogen applied and date of leaf sampling. N = pounds of nitrogen per acre applied as ammonium nitrate in the amounts indicated by the numbers in the subscripts thereto and P = 200 pounds per acre of P_2O_5 added to the soil as treble super phosphate. The arrows indicate the dates of irrigation subsequent to the fertilization of May 14.

Field H.—The results of the petiole analyses for field H are presented in Figure 6. The beets were planted on March 22, fertilized on May 9, and irrigated for the first time thereafter on May 28. Just as in fields M, W, R, C and K, the fertilizer was not effective until the beets had been irrigated. Thus in the samplings for April 29, May 15 and May 27, the differences in nitrate concentrations were not statistically significant, although the lowest values on May 15 and 27 were for the untreated beets. On June 10 petiole samples were taken for the first time after irrigation, and now the nitrate-nitrogen concentrations differed greatly. Values for the plots treated with 240 pounds of nitrogen per acre averaged approximately 18,000 parts per million, whereas those for the untreated plots averaged below 2,000 parts

per million. On the next sampling, June 24, the beets from the untreated plots were well below the critical nitrate-nitrogen concentration, whereas the concentration for the beets treated with nitrogen decreased sharply since the previous sampling on June 10. On subsequent samplings, further decreases in nitrate-nitrogen took place, with the beets receiving treatments 80, 160, 240 and 240 + P reaching the critical concentration on July 14, July 29, August 29 and September 3, respectively.

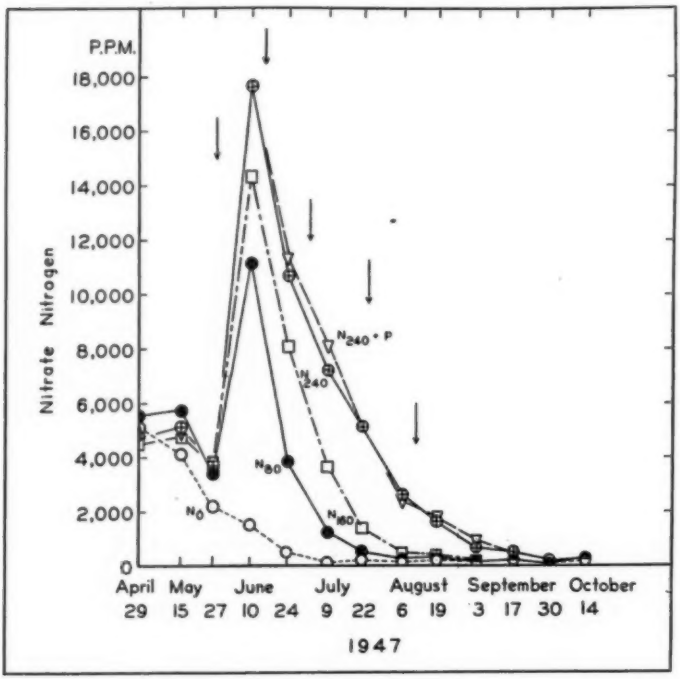

Figure 6. Nitrate-nitrogen (dry basis) of recently "matured" petioles for field H (Yolo fine sandy loam) as related to the amount of nitrogen applied and date of leaf sampling. N = pounds of nitrogen per acre applied as ammonium nitrate in the amounts indicated by the numbers in the subscripts thereto and P = 200 pounds per acre of P_2O_5 added to the soil as treble super phosphate. The arrows indicate the dates of irrigation subsequent to the fertilization of May 9.

The results of the petiole analyses (Figure 6) were again in accord with the yields (Figure 2). There was a large increase in yield for the first 80-pound nitrogen application, a smaller increase in yield for the 160-pound application, and thereafter no significant increases in yield took place. The untreated beets in this field gave an average sugar concentration of 18.3

percent, and as in the other fields the addition of nitrogen decreased the sugar percentages significantly. It is also of interest to note that in no case did the average sugar concentrations of the fertilized beets equal those of the unfertilized beets, even though the plants had been deficient in nitrogen for 3 months, as in the case of the 80-pound application. Again this is a problem for further study.

Judging from the results of the petiole analyses, the irrigation of May 28 occurred in time to maintain the nitrate concentration of the beets above the critical level, for shortly thereafter the untreated beets became deficient in nitrogen. The petiole analyses also illustrate the importance of adding water after fertilization. In this particular field the delay of approximately 4 weeks in irrigation after fertilization may not have been too serious because the fertility of the field was sufficient to provide the beets with enough nitrogen to keep them above the critical concentration until the beets were watered; but in other fields of this investigation such a delay most likely would have resulted in a decrease in beet yields.

Field C.—In this field the beets were planted on April 19, fertilized on May 23 and irrigated for the first time thereafter on June 19. The first three petiole samplings prior to irrigation were made on May 27, June 3 and June 18. None of the differences in petiole nitrate observed on these dates was statistically significant, even though the values for the petioles of the untreated beets collected on June 18 are lower than any in this field (Figure 7). The sampling of July 2, which was subsequent to the irrigation of June 19, showed that the beets had now absorbed the nitrogen added to the soil. The differences in petiole nitrate for the various amounts of nitrogen added, however, were the smallest of any experiment conducted during 1947. It is true that the 80-pound application produced a marked increase in nitrate concentration, but further increases from adding 160 and 240 pounds of nitrogen to the soil were relatively small. The untreated beets of field C reached the critical nitrate-nitrogen concentration on July 26, whereas the values for the remaining treatments, 80, 160, 240 and 240 + P, passed through this zone on August 17, September 2, September 8 and September 7, respectively.

The relatively small differences in nitrate-nitrogen values of the petioles from field C for the 80 and 160 applications may be associated with the inadvertent fertilization of all plots with 60 pounds of nitrogen applied as ammonia in the irrigation water on July 7. This explanation, however, is difficult to reconcile with the fact that there was no change in the slope of the nitrate curve for the untreated beets on July 15, the first sampling thereafter. Either the nitrogen was not absorbed by the plants, or it was not converted to nitrate so as to be reflected in the nitrate analysis of the petioles, or the growth rates of the beets were so rapid as to include in stride the extra 60 pounds of nitrogen applied.

In field C the beets of all treatments were below the critical concentration approximately 4 months before harvest, and accordingly no large differences in sugar concentrations should have been expected (2). The sugar analyses for these beets, in contrast to those of pot experiments, showed

that the concentrations of sugar decreased significantly with the nitrogen applications.

The beet yields (Figure 2), as in the other experiments, confirmed the observations made in the petiole analyses. An increase in yield over the control beets (60-pound) was observed for the 80 + 60-pound application and still higher yields for the 160 + 60-pound application, but no further yield increases were observed for the 240 + 60-pound application either with or without phosphorus. From the practical standpoint the results of the petiole analysis indicate that the field was well supplied with nitrogen until the end of July. Apparently nitrogen applications to field C as late as June or July would be beneficial to the crop, if also, harvesting is delayed, as it was in this experiment.

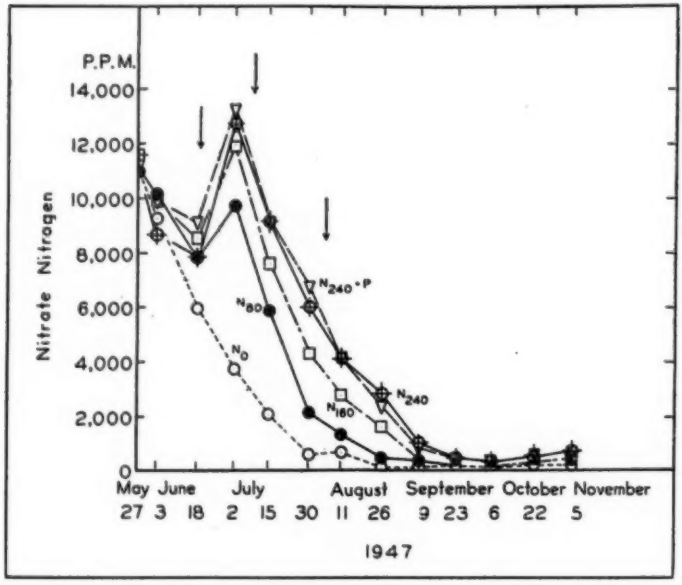

Figure 7. Nitrate-nitrogen (dry basis) of recently "matured" petioles for field C (Columbia clay loam) as related to the amount of nitrogen applied and date of leaf sampling. N = pounds of nitrogen per acre applied as ammonium nitrate in the amounts indicated by the numbers in the subscripts thereto and P = 200 pounds per acre of P_2O_5 added to the soil as treble super phosphate. In addition to these treatments, 60 pounds of nitrogen were applied inadvertently to all the plots as ammonia in the irrigation water of July 7. The arrows indicate the dates of irrigation subsequent to the fertilization of May 23.

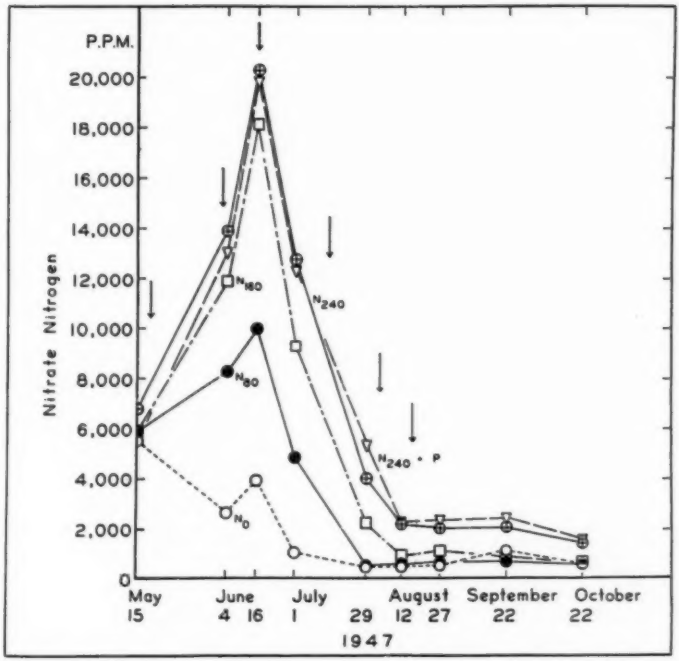

Figure 8. Nitrate-nitrogen (dry basis) of recently "matured" petioles for field K (Yolo fine sandy loam) as related to the amount of nitrogen applied and date of leaf sampling. N = pounds of nitrogen per acre applied as ammonium nitrate in the amounts indicated by the numbers in the subscripts thereto and P = 200 pounds per acre of P_2O_5 added to the soil as treble super phosphate. The arrows indicate the dates of irrigation subsequent to the fertilization of May 16.

Field K.—The results of the petiole analyses of field K are presented in Figure 8. This field was planted on March 14, fertilized on May 16 and irrigated on May 20. The petioles taken on May 15, just prior to fertilization, did not differ significantly in nitrate concentration. On June 4, following the irrigation of May 20, the nitrate concentrations of the petioles, as in the other experiments, were related to the amounts of nitrogen added to the soil. On June 16 the nitrate concentrations of the petioles again increased, and this time, in contrast to the results of the June 4 sampling, the values also increased for the untreated plots.

From this increase in nitrate, one may conclude that the rate of nitrate formation in the soil was temporarily greater than the rate of its utilization by the plants, thus resulting in an increase of nitrate within the plants. By

July 1, the nitrate concentrations had decreased to such an extent that the beets of the untreated plots were now below the critical concentration, whereas all others were still well above this level. Thereafter the beets for the 80- and 160-pound applications reached the critical concentration on July 26 and August 12, respectively. The beets for the higher nitrogen applications failed to reach this level even at the time of harvest.

This unusual condition of the petioles for the 240-pound applications may be associated with a shortage of water which took place shortly after the beets were irrigated for the last time on August 8. Again, this water shortage was most likely responsible for the failure to obtain a significant increase in beet or sugar yields for any of the nitrogen-treated plots. While the sugar concentrations of the beets in this field were not influenced by 80 pounds of nitrogen, significant decreases were observed for the larger amounts applied. It is of interest, too, to mention that frequent observations of a field during the growing season may often explain apparent anomalies between plant analyses and final yields, such as took place in this field. Although the nitrate analyses of the petioles from this field were similar to those in which large differences in yield had been obtained, the shortage of water prevented the full utilization of the nitrogen which had been absorbed by the beets earlier in the growing season.

Discussion

In reviewing the beet yields observed in the present series of experiments, it is of interest to note that significant increases in yield were obtained from the use of nitrogen in all but one of the 7 locations in the Woodland area of the Sacramento valley for 1947. These increases in yield are in accord with the expectations of the plant nutrient surveys made some years ago in this area (3) and are also in harmony with the results of the present petiole analyses, even though the yields of the untreated plots were as low as 5.9 tons per acre for field W and as high as 25.0 tons per acre for field R (Figure 2). The low yield of 5.9 tons in field W was largely the result of root rot damage to the beets. Allowing for this damage, the lowest yield for the untreated plots would have been 10.6 tons per acre, which is still less than half of the highest untreated plot yield for field R.

In spite of this wide variation in yield, the first 80-pound application of nitrogen gave significant increases in all but one field. The smallest increase in yield, 2.4 tons per acre, was observed for field C, where 60 pounds of nitrogen had been applied inadvertently throughout the experimental field; whereas the largest increase, 5.8 tons per acre, took place in field H. For the plots treated with 240 pounds of nitrogen per acre, the lowest average yield, 19.6 tons per acre, was observed in field W, and the highest, 28.7 tons per acre, for field R. Yield increases over the untreated plots for the 240-pound nitrogen application were 9.0, 7.5, 6.9 and 6.7 tons per acre for fields W, H, M and Y and only 3.3 and 3.7 tons per acre for fields K and R.

Some of the variations in yield for the untreated plots and the variations in response to nitrogen for the fertilized plots at the different locations are undoubtedly associated with local differences in climate within the Woodland area. Of greater significance in producing variations in yield increases for the same nitrogen treatment, however, are crop histories and cultural

practices, including previous fertilizations at each location. In relation to the cultural practices, variations in the date of planting, thinning, irrigating and harvesting are quite likely to have had a profound influence upon the yields obtained at the time of harvest.

In the present experiments, the small yield increase from nitrogen for field K was clearly associated with a shortage of water as observed late in the growing season, whereas for field R the beets were harvested prematurely. That such large differences in yield and responses to fertilization exist within an area should serve as a challenge to growers, field men and scientists to attempt to raise production for all fields to the highest level possible for a given climatic zone.

The use of petiole analysis as a tool for observing the nutritional changes taking place within the plants prior to and subsequent to fertilization has been of great value in the present experiments. As a rule, nitrate supplies in the petioles were found to be adequate for beet growth early in the growing season, but as the season progressed, the nitrate concentrations decreased rapidly in the petioles of all unfertilized beets, causing thereby decreases in beet growth. In the fertilized beets, the rapid decline in nitrate concentration early in the season stopped well above the critical concentration of 1,000 parts per million of nitrate nitrogen; and, in fact, the nitrogen added to some fields was sufficient to maintain the nitrate concentrations of the petioles above the critical level even to the time of harvest (Figures 1 and 8).

The need for the addition of water shortly after fertilization was demonstrated clearly by the results of the petiole analyses. It was only after water had been applied that the ammonium nitrate was effective in causing large increases in nitrate concentration of the petioles (see particularly Figures 3, 6, 7). Most likely, other sources of nitrogen would have produced similar increases in nitrate concentration of the petioles. This has been found to be true for ammonium sulfate in pot experiments (2) and more recently in a field experiment (1) for calcium nitrate, sodium nitrate and urea.

The amount of nitrogen required to maintain the nitrate concentration above the critical level is also indicated by the petiole analyses. In fields R and M (Figures 1 and 3) the 80-pound application maintained the nitrate concentration above this level for most of the growing period. In all others the 80-pound application was soon depleted by the plants, whereas in field W (Figure 5) even the 240-pound application appeared to be insufficient to meet the needs of the crop. On the basis of these observations it is possible to select the approximate amount of nitrogen for maintaining a satisfactory nitrate level in the plants up to and prior to harvesting the beets. Similarly, nutrient inventories taken yearly would aid materially in making adjustments in the fertilizer program for each crop grown on a field.

The results of the petiole analyses indicate that all fields were adequately supplied with potassium, and all but field Y, with phosphorus (unpublished data of our laboratory). In field Y the phosphate concentrations in the petioles from all plots were near the critical level for part of the growing season regardless of the fertilizer treatment, which included the addition of 200 pounds of P_2O_5 with 240 pounds of nitrogen per acre.

Apparently in field Y, in which a different method of application was used, the phosphorus added to the soil either failed to reach the root zone of the beets, or perhaps the amounts added were insufficient to overcome the fixation of phosphorus by the soil and still leave enough for plant growth. If one judged the need for phosphorus in field Y from the yields alone, the supply of phosphorus, as in the other locations, would have been assumed to be adequate.

The petiole analyses, however, indicated that there is a definite phosphorus problem on this field, such as placement within the root zone, fixation by the soil and time of application. In all other fields the beets were high in phosphorus and the phosphorus fertilizations had no effect on the yields or on the petiole phosphorus, even though the method of fertilization was effective in other experiments on fields low in phosphorus.

The relationship of the nitrate content of the petioles to the sugar concentration of the beets and to beet yield is of particular interest in sugar production. The greater the number of days the beets are below the critical concentration of 1,000 parts per million of nitrate-nitrogen, the higher the concentration of sugar in the beets and the lower the beet yields (Figure 2). Conversely, the more days the beets are above the critical concentration, the higher the beet yields, which occasionally may not result in more sugar production because of the lowering of the sugar concentrations of the beets (field R, Figure 1). These decreases in sugar concentration following nitrogen fertilization, as in fields Y, H and C (Figures 4, 6 and 7), occurred even after long periods of nitrogen starvation prior to harvest, which is contrary to that which would have been anticipated from the results of pot experiments (2).

Summary

Petiole samples from 7 fertilizer experiments were collected at 2-week intervals during 1947, starting from the time of planting and continuing until harvest. The results of the analyses showed that the fields were at different degrees of nitrogen deficiency and this was related to beet yields and sugar concentrations. In general, the earlier in the growing period the nitrate values fell below the critical concentration of 1,000 parts per million of nitrate nitrogen and the more days the values remained below this level, the lower the yield and the higher the sugar concentration. Conversely, the longer the beets remained above the critical concentration, the higher the yield and the lower the sugar concentration.

The petiole analyses, aside from indicating a need for nitrogen fertilization, gave useful information as to the time of fertilization, the amount of nitrogen required for a given beet field, the need for water after fertilization and the kind of nutrients absorbed from the fertilizer applied, as for example, in the field low in phosphorus, the phosphorus added was not taken up by the beets. In the 6 fields high in petiole phosphorus, the phosphorus fertilization had no effect on the yields, even though the fertilizations in these fields were made by a method proven to be effective on fields low in phosphorus. All fields, on the basis of the petiole analyses, were well supplied with potassium.

Significant increases in beet yields from the nitrogen fertilizations were observed in 6 out of 7 fields investigated. This was in accord with earlier findings obtained through petiole analyses of fields in the Woodland area. A shortage of water was largely responsible for the failure to get a signicant increase in yield in the seventh field, even though the petiole analyses and field observations indicated a need for nitrogen.

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Effects of Growth-Promoting Substances on Sugar Beets

J. T. ALEXANDER AND C. E. CORMANY[1]

The application of dilute solutions of trace elements directly to the leaves of deficient plants, particularly plants deficient in iron, has often resulted in the elimination of the deficiency symptoms. The remarkable results obtained by using 2,4-D and related growth-promoting substances also shows how readily these compounds may enter the plants through the above ground structure. It was felt that perhaps in the case of the sugar beet plant spraying the leaves would offer a means of furnishing certain materials necessary for optimum growth and sugar formation not readily supplied otherwise. With this in mind, sprays containing various nutrients, trace elements, growth-promoting substances and organic mixtures were applied to sugar beet foliage in the field during the summer of 1949 at Swink, Colorado.

Procedure

Eighteen treatments, as listed in Table 1, are included in this exploratory test. Small plots of .004 acre were sprayed four times at two-week intervals. The first application was applied August 22, 1949. The plots were sprayed late in the growing season in an effort to exert a ripening or maturing influence on the beets. It was hoped an increase in sucrose percentage would result. Both sucrose and yield data were secured, however.

All substances were mixed with water and applied at the rate of 31.25 gallons per acre.

A randomized block design was used with nine replications of each treatment. The eighteen treatments were split into two tests of nine treatments plus a check.

The treatments, concentration of the sprays expressed in parts per thousand and pounds per gallon, sugar per acre, yield, and sucrose percentage are shown in Table 1.

Stands on all plots were comparable and not a factor in the test.

Results

None of the treatments affected yield significantly. Several of the treatments did influence the percent sucrose, however. A mixture of iron, magnesium and potassium sulfate applied at the rate of 13⅓ pounds each, per acre, lowered the percent sucrose a significant amount. Copper sulfate applied at the rate of 20 pounds per acre and pregnant cow urine applied at the rate of 125 gallons per acre also lowered the sugar percent significantly. Magnesium sulfate sprayed on the leaves at the rate of 20 pounds per acre raised the percent sucrose significantly at the 5 percent level. In addition, potassium chloride at the 40-lb. rate closely approached significance and should be considered in further testing.

Distinct burning of the foliage was noted where iron, copper and zinc compounds were applied in concentrations of 19 parts per thousand. In fact,

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burning was noted in every case where iron (ferrous) sulfate was applied. The leaves sprayed with the ion-exchange regenerate solution exhibited slight burning.

The plots which were sprayed with NuGreen, cow urine and the ion-exchange regenerate solution showed a dark green color normally attributed to beets having an abundant nitrogen supply. As all three of these sprays contained nitrogen in varying amounts, it may be assumed that the plants in these plots were able to assimilate an appreciable amount of this element.

Table 1.—Concentration and Acre Production of Various Spray Treatments Applied to Sugar Beets at Swink, Colorado—1949.

Treatment	Spray Concentration			Lbs. sugar per acre	Tons per acre	Percent sucrose
	Quantity per acre	Parts per thousand	Lbs. per gallon			
Test A						
1 Potassium chloride	40 lbs.	38.00	0.32	5,378	16.668	16.14
2 Magnesium sulfate	40 lbs.	38.00	0.32	5,016	15.814	15.87
3 Potassium chloride	20 lbs.	19.00	0.16	4,945	15.712	15.83
4 Magnesium sulfate	20 lbs.	19.00	0.16	4,919	15.252	16.17[2]
5 Manganese sulfate	20 lbs.	19.00	0.16	4,900	15.345	15.91
6 Zinc sulfate	20 lbs.	19.00	0.16	4,869	15.935	15.30
7 NuGreen (Dupont) Soluble Nitrogen (43%)	20 lbs.	19.00	0.16	4,778	15.156	15.75
8 Check	———	———	———	4,715	15.032	15.69
9 Iron sulfate	20 lbs.	19.00	0.16	4,471	14.621	15.26
10 Copper sulfate	20 lbs.	19.00	0.16	4,203	14.011	15.00[1]
		General Mean		4,819	15.357	15.69
		Diff. for Sig.		ns	ns	.48
Test B						
11 Check	.....	.....	.....	4,771	14.720	16.14
12 Sugar Beet Molasses Sp. Gr. 1.414 approx.	328 lbs. (27.8 gal.)	.....	2.65	4,741	14.737	16.07
13 Liquid P_2O_5 (52%)	20 lbs.	19.00	0.16	4,577	14.298	16.02
14 Ion Exch. Reg. (3.8%) N.Sp.Gr. 1.110	1158 lbs. (125 gal.)	.....	9.30	4,476	13.945	15.97
15 P-chlorophenox of acetic acid (Sure-Set)	2.3 gal.	00.03	.....	4,447	14.005	15.82
16 Sodium salt of a-napthyl acetic acid (App-1-Set)	10 lbs.	9.60	0.08	4,395	13.774	15.96
17 Whole raw milk	27.8 gal.	.....	.....	4,386	13.991	15.60
18 Mixture of $CuSO_4$, $FeSO_4$, $MnSO_4$, $ZnSO_4$—5 lb./ each	20 lbs.	19.00	0.16	4,292	13.721	15.59
19 Pregnant cow urine	125 gal.	.....	.....	3,960	13.466	14.69[1]
20 Mixture of $MgSO_4$, K_2SO_4, $FeSO_4$—13.33 lb/ each	40 lbs.	38.00	0.32	3,592	12.103	14.81[1]
		General Mean		4,363	13.876	15.67
		Diff. for Sig.		ns	ns	.75

[1] Significantly lower than the check at 5% level.
[2] Significantly higher than the check at 5% level.

Discussion

This exploratory test was designed primarily to discover what, if any, influence these sprays might have on the percent sugar in the beets when applied late in the season. Had they been applied in the growing season a yield response might have been shown. This is particularly so of the nitrogen-bearing sprays and growth-promoting substances and, in all probability, liquid phosphoric acid.

With but one exception, the plots having the lowest sucrose percent were those which exhibited the most burning. These plots which were sprayed with the iron, copper, and zinc compounds had started to grow new tissue to replace the burned leaves and thus reduced the carbohydrate reserve. The plot which was the exception was the one treated with pregnant cow urine. These plots showed no burning of the leaves. They did exhibit what appeared to be nitrogen stimulation, however. It may be possible that this spray stimulated the vegetative growth of the beets on these plots to such an extent that maturity was delayed.

The only plots which showed an increase in sugar percent were those sprayed with potassium, magnesium and manganese compounds. This may indicate that such compounds may be used as a spray late in the growing season to hasten maturity and increase the storage of sugar.

Summary

Eighteen substances were sprayed on sugar beet foliage in the field at the rate of 31 gallons per acre. Four successive applications were made during late summer. None of the treatments was found to increase yields.

Two spray treatments, a mixture of iron, magnesium, and potassium sulfate, applied 3⅓ pounds each per acre for each spray application, and pregnant cow urine applied at the rate of 31 gallons per acre per each spraying, significantly depressed the sugar percent. Copper sulfate was also found to have a significantly depressing effect when applied at the rate of 5 pounds per acre in each of four sprayings. In fact, in all treatments containing iron, zinc and copper compounds, a depression of sucrose percent was shown.

Sucrose content was raised significantly by an application of 5 pounds of magnnesium sulfate per acre for each spraying. Potassium chloride at the rate of 10 pounds per acre per each spraying approached significance.

Results from this exploratory test encourage further investigation as to times and rates of application as well as new compounds.

A Report on Nutrient Spray Tests on Sugar Beets

ANDREW R. DOWNIE AND J. F. SWINK[1]

Plants are capable of absorbing many chemicals through their leaf surfaces. Many of the so-called trace elements can be absorbed by the leaf, then translocated to various parts of the plant. Also, some of the growth-promoting substances may be absorbed in this manner. There is some evidence that beneficial results might be obtained by spraying some of the nitrogen-containing materials on foliage of growing plants.

The above considerations were influential in the spray tests which are reported here. Field tests were made in 1948 and 1949 to determine the effect of spraying water solutions or suspensions of various chemicals on the foliage of sugar beets.

Experimental Procedure

The chemicals tested were dissolved or suspended in water so that a uniform application of approximately 30 gallons of spray material was applied per acre.. The plot size was three rows wide and 50 feet long with the middle row being harvested for yield and sucrose records. All of the materials were applied with a continuous pressure hand sprayer.

The first applications of spray materials were made about the middle of July with subsequent applications being made at 10 to 14 day intervals.

Table 1.—Chemicals, amounts applied per acre, and yields obtained in spray test at Rocky Ford—1948.

Treatment	Total Amt. Appl'd Acre	Tons Beets per Acre	% Sucrose	Lbs. Sugar per Acre
15. Milk	16 gal.	18.08	14.87	5,372
14. O-52-0 (liquid)	3.7 lbs.[1]	17.69	14.81	5,222
9. Quick Root (0.15 Indole Butyric Acid)	1.0 lbs.	17.41	14.98	5,221
3. Manganese Sulphate	8.9 lbs.	17.46	14.75	5,139
10. App-L-Set (Naphthyl Acetic Acid)	1.0 lbs.	16.86	14.56	4,900
8. Molasses	15.2 lbs.	16.08	14.90	4,799
13. 5-10-5 (liquid)	7.6 lbs.	15.97	14.90	4,783
7. Sugar (Sucrose)	9.8 lbs.	15.56	14.94	4,660
5. Copper Sulphate	11 lbs.	15.66	14.49	4,530
2. Magnesium Sulphate	8.9 lbs.	15.50	14.56	4,314
12. 11-48-0	34.2 lbs.	15.29	14.65	4,480
16. Check	.....	14.23	15.21	4,318
11. 2,4-D (83%)	6.66 grams	14.44	14.86	4,312
1. Boron	11 lbs.	14.42	14.75	4,282
6. Iron (ferrous) Sulfate	9.8 lbs.	13.90	14.50	4,061
4. Zinc Sulphate	8.9 lbs.	13.36	14.40	3,900
General Mean		15.74	14.76	4,656
Sign. Diff. (19:1)		2.90	.74	893

[1] 1.92 pounds P_2O_5 per acre.

[1] Plant Pathologist and Research Assistant, respectively, American Crystal Sugar Company, Rocky Ford, Colorado.

Test in 1948

An exploratory test was conducted at Rocky Ford, Colorado, in 1948. Only two spray applications were made in this test. The first application was applied on July 2 and the second application on July 15. This test was set up as a randomized block with six replications.

The various chemicals used, the total amount of each application per acre, and the yield data are presented in Table 1. The data presented in this table show significant increases in tonnage for milk, liquid phosphoric acid, quick root, and manganese sulfate treatments. Of the four materials mentioned, only manganese sulfate did not result in a significantly higher sugar per acre yield.

Table 2.—Nutrient-Hormone-Trace Element Spray Test, Rocky Ford—1949

Treatment	Tons Beets per Acre	% Sucrose	Lbs. Sugar per Acre	Tot. Amt. per Acre
15. Calcium Oxylacetate	25.07	17.56	8,810	2.57 lbs.
9. Copper Oxide	24.94	17.52	8,787	10.28 lbs.
14. 2,4-D	25.09	17.47	8,775	13.32 grams
5. App-L-Set	24.11	17.49	8,465	1.71 lbs.
6. Manganese Sulphate	24.18	17.46	8,456	10.28 lbs.
2. Skim Milk	24.63	17.11	8,446	29.04 gallons
10. Levulose	24.26	17.30	8,407	17.0 lbs.
11. Dextrose	23.67	17.63	8,353	17.0 lbs.
12. Luvulose and Dextrose	23.83	17.50	8,339	8.5 lbs.-8.5 lbs.
13. Sucrose	23.91	17.35	8,320	17.0 lbs.
8. Monosodium Glutamate	23.96	17.23	8,269	10.28 lbs.
4. Quick Root	23.87	17.25	8,247	1.71 lbs.
16. Check	23.72	17.35	8,236	———
7. Molasses	23.43	17.34	8,159	25.6 lbs.
3. 0-52-0 (Liquid Phosphate)	22.91	17.62	8,079	10.64 lbs.
1. Milk	22.89	17.40	7,965	29.04 gallons
General Mean	23.96	17.41	8,356	
Sign. Diff. (19:1)	2.29	.62	907	

This test indicated that the chemicals applied affected only the yield and not the sucrose content.

Tests in 1949

On the basis of the results obtained in 1948, spray tests were carried on in 1949 at Clarksburg, California, Rocky Ford, Colorado, Mason City, Iowa, and at Chaska and East Grand Forks, Minnesota. All tests were sprayed a total of four times during the season.

The tests at Mason City, Chaska and East Grand Forks were set up as 6x6 Latin squares. The chemicals used were: Cooper oxide (spray grade), App-L-set, liquid phosphoric acid, milk and manganese sulfate. None of the treatments in any of these three tests was significantly different from the untreated check. It was noted that where Cercospora leaf spot was present the plots sprayed with copper oxide showed the lowest incidence of infection; however, in no case did this seem to affect yield.

The test conducted at Clarksburg, California, consisted of four treatments: milk, 17-7-0, milk—beets side-dressed with 17-7-0 at the rate of 75 pounds of plant food per acre, and the untreated check. There were no significant differences in this test.

The results of the test conducted at Rocky Ford are presented in Table 2.

As was the case in the other tests conducted in 1949 no significant differences were obtained in the Rocky Ford test.

Discussion

The explanation for the variation in results between the two years' tests cannot be explained. Chemicals which were common to both years' tests were all obtained from the same container with the exception of the milk treatment. It is very evident that before any conclusions can be made additional testing is necessary.

Summary

In an experiment conducted in 1948 in which various chemicals were sprayed on the foliage of beets significant increases in yield were obtained with milk, liquid phosphoric acid, quick root, and manganese sulfate.

Similar experiments made in 1949 did not substantiate the above findings.

Effect of Some Growth-Regulating Substances on Sugar Beet Development

R. T. NELSON[1]

The course of development of sugar beets is affected materially by climatic and soil factors, especially with regard to sugar content. A high level of nitrates in the soil and large, rapidly growing tops at time of harvest are associated with low sugar content in the beet root. In practice it is frequently impossible to balance fertilization and irrigation methods so that both high yield and high sugar content will be obtained. A need for supplemental treatments exists which cannot be fulfilled without expanded information. Beginning with results obtained in 1947, this report presents data on several treatments other than the major nutrient elements.

Material and Methods

Two tests conducted near Gering, Nebraska, in 1947, included growth-regulating substances and other treatments aimed at promoting root development and in some cases lessening of top development. The tests, similar in design, each having six replications, were conducted on two fields on plots 6 rows wide and 28 feet long. For harvest results, the four center rows of each plot were used. All materials used as a spray were applied in rather large volumes of water at low pressure with hand-operated sprayers. Subsequent tests were conducted near Longmont, Colorado, in 1948 and 1949.

The treatments used in tests conducted during 1947 and 1949 are given in Tables 1 and 2, respectively. The treatments used in a single small trial conducted during 1948 are mentioned with the harvest results in the following sections.

Table 1.—Treatments used in tests at Gering, Nebraska, 1947

Tr. No.	Treatment
1	Check.
2	Sprayed 2,4-D on leaves at the rate of ⅛ pound (70 percent sodium salt) per acre, July 21.
3	Same as No. 2, except application 1/16 pound per acre.
4	Sprayed in solution 10 pounds Borax per acre onto crowns of beets, July 21. No attempt was made to cover all the leaves.
5	Manually trimmed outside leaves from beet crowns on July 21, August 9, and August 27 to about 10 leaves per beet.
6	Sprayed in suspension 3 quarts Sprout Inhibitor per acre (44 percent methyl ester of alpha naphthalene acetic acid) September 12.
7	One-half rate of treatment 6.
8	Sprayed at the rate of 100 gallons per acre a solution containing 40 PPM 1, naphthalene acetic acid (1 pound Apple Set—Dow A-214 per acre) July 21, August 9, and August 27.
9	Removed, by cutting, center leaves and portion of crown (supposedly active growing point) on August 27.

[1] Agronomist, The Great Western Sugar Company, Agricultural Experiment Station, Longmont, Colorado.

Table 2.—Amount of growth-regulating substance, in rate per acre, applied as sprays (80 gallons per acre) in tests at Longmont, Colorado, 1949.

Tr. Nos.[1]	Treatment[2]
1	Check, no treatment
2, 10 and 18	10 grams (1/45 lb.) 2,4-D acid, as sodium salt (.045 gram molecule)
3, 11 and 19	20 grams (1/23 lb.) 2,4-D acid, as sodium salt (.091 gram molecule)
4, 12 and 20	8.4 grams p-chlorophenoxyacetic acid (.045 gram molecule)
5, 13 and 21	16.9 grams p-chlorophenoxyacetic acid (.091 gram molecule)
6, 14 and 22	10 grams 2,4-D + 8.4 grams p-chlorophenoyacetic acid
7, 15 and 23	10 grams 2,4-D + 20 grams indol 3 acetic acid
8, 16 and 24	20 grams sodium salt of 4-chloro-o-toloxyacetic acid
9, 17 and 25	20 grams 2,4- dibromophenoxyacetic acid (as sodium salt)

[1] Treatments 2-9 were applied about June 1
Treatments 10-17 were applied about July 1
Treatments 18-25 were applied about August 1
[2] No plot was treated more than once.

Results and Discussion

The tests conducted at Gering, Nebraska, were placed on fields which had a history of producing low-sugar-content beets. Yields, however, had always been good, suggesting no particular nutritional deficiency. The top growth on beets in the area frequently approaches the weight of the roots. Treatments were selected with an aim to promote root growth or discourage top growth, as the latter had appeared to flourish at the expense of root development and sugar storage. The results obtained are given in Table 3.

Table 3.—Yield of beets, sugar percentage, total sugar, and yield of tops in percent of root yield for different treatments (mean values of six replications per farm).

	Weber Farm				Grassmick Farm			
Tr.[1] No.	Beets per Acre	Sugar	Sugar per Acre	Top Wt./ Root Wt.	Beets per Acre	Sugar	Sugar per Acre	Top Wt./ Root Wt.
	(tons)	(percent)	(pounds)	(percent)	(tons)	(percent)	(pounds)	(percent)
1	18.96	15.4	5,840	63	19.07	16.1	6,141	55
2	17.46	12.7	4,435	39	15.29	13.5	4,128	38
3	18.50	13.5	4,995	47	17.68	14.6	5,163	38
4	19.37	15.4	5,966	62	18.08	16.0	5,786	54
5	15.39	13.3	4,094	50	15.32	15.3	4,688	47
6	18.88	14.1	5,324	65	17.81	15.2	5,414	50
7	20.86	14.4	6,008	58	18.48	15.4	5,692	52
8	18.54	14.6	5,414	61	19.35	15.6	6,037	54
9	17.51	14.3	5,008	52	16.49	15.5	5,112	38
Gen. Mean	18.39	14.2	5,223	55.2	17.51	15.2	5,351	47.3
LSD 5% pt.	2.30	.72	754	....	1.89	.49	602	....
LSD 1% pt.	3.08	.97	1,009	....	2.53	.66	806	....

[1] For description of treatments according to number, see table 1.

None of the results presented in Table 3 was significantly better than the check (treatment 1). Some treatments caused a significant reduction in yield and several treatments caused a real reduction in sugar percentage. The 2,4-D applications (treatments 2 and 3) were obviously too heavy. The immediate growth of roots and old leaves following treatment appeared unusually rapid. This was followed by what appeared to be a prolonged inactive period of growth of about two-months' duration. Then, just before harvest, considerable leaf growth was again noticed but the total top growth remained

less than for the check. The latter is apparent from the top weights given in percent of the root weight, Table 3, treatments 1-3. Beets on plots receiving treatment 5, periodic removal of the older leaves, grew additional leaves rapidly to maintain rather high its top weight in relation to root weight. Massive tops were grown at the expense of total root yield, even though top weights of 35 to 40 percent of root weights at harvest time have been reported as apparently optimum. The methyl ester of alpha naphthalene acetic acid (treatments 6 and 7) and alpha napthalene acetic acid (treatment 8) had no visible effect on beet development or yield as measured at harvest. Cutting out the apex bud and central leaves, even though done rather late in the season, resulted in the activation of other buds and a reduction in root development.

During 1948, due to adverse weather conditions throughout the spring, stands of beets were not good and rather unsuitable for test purposes. Nevertheless, it was felt that from certain treatments observations on visible effects at least might be obtained. A test was made with 8 treatments (10 including checks) which were applied August 10. The treatments and harvest results obtained on October 14 appear in Table 4.

Table 4.—Harvest results (mean 2 replications) for various treatments. Longmont, 1948.

Treatment and rate per acre of active ingredient	Beets per A	Sugar	Sugar per A	Stand of Beets per 100'
	(tons)	(percent)	(lbs.)	
150 grams 1 naphthalene acetic acid	16.88	14.05	4,743	87
1,500 grams 1 naphthalene acetic acid	17.01	14.50	4,933	77
0.7 grams p-chlorophenoxyacetic acid	19.06	14.45	5,508	90
7 grams p-chlorophenoxyacetic acid	14.83	16.12	5,199	67
Check	15.49	14.90	4,616	81
400 grams methyl ester of 1 naphthalene acetic acid	16.82	14.47	5,038	77
4,000 grams methyl ester of 1 naphthalene acetic acid	18.32	13.12	4,809	92
1.6 grams 2,4 dichlorophenoxyacetic acid	17.91	14.70	5,266	69
16 grams 2,4 dichlorophenoxyacetic acid	24.74	12.70	6,284	96
Check	16.77	14.95	5,014	83
General Mean	17.79	14.45	5,141	....
CV (%)	11.26	8.07	.....	....
Sm/Gen. M (%)	7.96	.....	.....	....
LSD 5% pt.	4.53	ns[1]	ns	....

[1] Differences not significant by F test.

As indicated in Table 4, rates up to 3.3 pounds alpha naphthalene acetic acid applied as a spray August 10 showed no response in yield. Similarly, applications of the methyl ester of alpha naphthalene acetic acid at rates up to 8.8 pounds per acre had no effect on yield or visual development of the beet. On the other hand, 16 grams (1/29 pound) 2,4-dichlorophenoxyacetic acid applied as the sodium salt in a spray August 10 resulted in a very definite visual response and an increase in yield of beets significant at odds of 19:1. Again the percentage of sugar was lowered and the total sugar per acre was not significantly higher.

Since 2,4-D did give an apparent stimulation in growth and p-chlorophenoxyacetic acid was suggestive of having a favorable effect on sugar percentage, it was felt that further testing should be done. Related substances p-chlorophenoxyactic acid, 4-chloro-o-toloxyacetic acid, 2,4-dichlorophenoxyacetc acid, and 2,4-dibromophenoxyacetic acid were tested on a close comparative basis in 1949. The rates of the phenoxy substances were in the order of 10 and 20 grams per acre but were adjusted slightly to give comparable rates on a gram molecular basis. The concentration of the sprays applied was of the order of 35 and 70 ppm. active ingredient. The percentage of the material striking the beet plants varied with the amount of foliage development, as the area between the rows was sprayed as well as in the row.

The results obtained at Longmont during 1949 are presented in Table 5.

Table 5.—Yield of beets, sugar percentage, total sugar and stand for different treatments (mean values of six replications per field).

Tr. No.	Field 1 Beets per Acre	Sugar	Sugar per Acre	Beets per 100′	Field 2 Beets per Acre	Sugar	Sugar per Acre	Beets per 100′
	(tons)	(percent)	(pounds)		(tons)	(percent)	(pounds)	
1	26.27	14.67	7,708	99	26.48	18.01	9,538	79
2	27.65	14.77	8,168	95	26.05	18.00	9,378	85
3	26.89	13.94[1]	7,497	98	26.25	17.69	9,287	82
4	26.63	14.27	7,600	101	26.28	17.97	9,445	82
5	25.72	14.74	7,582	98	25.66	18.06	9,268	79
6	26.49	14.79	7,836	96	25.34	17.96	9,102	85
7	25.92	14.92	7,735	96	24.96	18.00	8,986	86
8	26.67	14.70	7,841	94	24.54[1]	18.01	8,839[1]	83
9	25.11	14.85	7,458	105	25.50	17.93	9,144	81
10	26.62	13.90[1]	7,400	101	23.65[1]	17.60[1]	8,325[1]	78
11	25.74	14.47	7,449	105	25.55	17.08[1]	8,728[1]	87
12	27.41	14.12[1]	7,741	96	24.68[1]	18.02	8,895[1]	82
13	26.52	14.84	7,781	99	25.07	18.15	9,100	82
14	26.35	13.60[1]	7,167	99	24.84	17.59[1]	8,739[1]	84
15	26.42	13.62[1]	7,197	101	25.01	17.64[1]	8,824[1]	87
16	26.68	14.65	7,817	93	25.53	17.88	9,130	83
17	27.98	14.75	8,254	95	25.23	17.85	9,007	80
18	26.87	13.86[1]	7,448	92	24.22[1]	17.58[1]	8,516[1]	80
19	28.36	13.03[1]	7,391	100	24.96	15.87[1]	7,922[1]	81
20	26.01	13.97[1]	7,267	98	24.69[1]	18.12	8,948	80
21	25.78	14.05[1]	7,244	94	24.42[1]	18.25	8,913[1]	82
22	26.27	14.18	7,450	90	24.77[1]	16.44[1]	8,144[1]	84
23	24.86	13.94[1]	6,931[1]	95	24.53[1]	17.22[1]	8,448[1]	77
24	26.56	14.13[1]	7,506	95	25.33	17.89	9,063	81
25	25.48	14.37	7,323	94	25.37	17.80	9,032	81
Gen. Mean	26.45	14.29	7,559	....	25.16	17.70	8,907	....
CV (%)	6.72	2.75	7.26	....	5.40	1.86	5.71	....
Sm/Gen. M (%)	2.74	1.12	2.96	....	2.21	.76	2.33	....
LSD 5% pt.	2.15	.49	667	....	1.68	.35	622	....
LSD 1% pt.	2.85	.65	883	....	2.23	.47	824	....

[1]Statistically below check (tr. 1) at 5% level of significance.

The results with growth-regulating substances sprayed on the leaves of beets during the growing season of 1949 were, as in 1947, largely detrimental

to yield or sugar percentage, or both (Table 5). The effects seemed to be more harmful at the later dates of application. All the treatments used caused a significant reduction at odds of 19:1 in sugar percentage or yield of beets on one or both of the fields at one or more of the dates of application except the treatment including dibromophenoxyacetic acid, which produced neither a beneficial nor detrimental effect. On field 2, p-chlorophenoxyacetic acid treatments did not affect sugar percentage but did reduce yields. Conversely, 2,4-dichlorophenoxyacetic acid at the higher rate of application (treatments 11 and 19) caused a significant decrease in sugar percentage but not in yield of beets. The addition of indol 3 acetic acid to 2,4-D (treatments 7, 15 and 23) were equal, no better or worse, than the treatment of 2,4-D alone (treatments 2, 10 and 18).

Summary

Sprays containing alpha naphthalene acetic acid, 2-4-dichlorophenoxyacetic acid, and related substances applied to sugar beets during the growing season failed to give any conclusive favorable response in sugar content of beets or total sugar production. Several treatments with phenoxy compounds resulted in lower yields or lower sugar content of beets. Differences in response to growth-regulating substances were noted between fields and dates of application. Different end results obtained from treatment with strikingly similar compounds were noted. For example, p-chlorophenoxyacetic acid more frequently reduced the yield of beets without lowering the percentage of sugar, while 2,4-dichlorophenoxyacetic acid more frequently reduced the sugar percentage without lowering the yield of beets. That a change in end results could be obtained with such strikingly similar materials and in such small quantities, even though the reactions in these tests were mostly unfavorable, should serve to encourage additional studies in this unexhausted field of growth regulators as they affect sugar beet development.

The Effect of Fertilization on the Glutamic Acid Content of Sugar Beets In Relation to Sugar Production

I. General Aspects

LUCILE R. HAC, ALBERT C. WALKER, AND BASIL B. DOWLING[1]

Final waste from beet sugar factories using the Steffens process offers under favorable conditions an excellent by-product source of the dicarboxylic amino acid, glutamic acid. Concentrates of suitable Steffens filtrates can be processed to yield pure glutamic acid or the flavor intensifier, monosodium glutamate.

Studies were initiated necessarily by the tremendous variation found in the glutamic acid content of wastes from factories in different parts of the country and in different factories in the same area. It was considered advisable to learn the cause of this variation and, if possible, to determine how the glutamic acid content of wastes could be increased without detriment to the beet grower and sugar processor. Therefore, it is clearly evident that any information regarding glutamic acid must be related to its effect upon yield, sugar and processing operations if it is to be evaluated properly. For this reason our studies have been of a cooperative nature made possible by the assistance of many sugar companies, by various university workers, and by members of the Beet Sugar Development Foundation and the United States Department of Agriculture to whom we express our appreciation.

Our early studies indicated clearly that most of the differences in glutamic acid concentration of Steffens filtrates could be accounted for by differences in the glutamic acid content of the beet itself. This led to an investigation of the factors affecting the glutamic acid (or its precursors) present in the non-colloidal fraction of the beet, since only this portion reaches thin juice and may be expected to be carried over into concentrated Steffens filtrate. Work is now under way to determine the role of glutamine, the probable precursor of glutamic acid, in the growth of the sugar beet, the effects of various fertilizer treatments upon it, and the possible value of glutamic acid measurements as an indicator of the nitrogen status of the soil.

The present paper deals with analytical methods, field design and sampling techniques developed for accurate evaluation of glutamic acid, and their application to a study of the effects of fertilization on sugar beets. The responses to nitrogen fertilizer were measured at four periods of growth in a field in Yolo county, California, and the effects of manure, nitrogen and phosphorus were determined at harvest in an experimental plot on recently leveled land at Fort Collins, Colorado. Evidence is cited for considering the glutamic acid precursor, glutamine, as one of the major components of the storage nitrogen of the beet.

[1] International Minerals & Chemical Corporation, Woodland, California.

Measurement of Glutamic Acid in Sugar Beets

Glutamic acid studies are complicated by the fact that three compounds are involved: *Glutamine*, found in the beet itself; *∝pyrrolidonecarboxylic acid* to which glutamine is readily converted in solution, and *glutamic acid* which results from suitable hydrolysis of eithr glutamine or pyrrolidonecarboxylic acid.

Since all of the glutamic acid, or its precursor in the beet of interest to us, is contained in the non-colloidal fraction of the beet, some defecation treatment of whole beet material was necessary before glutamic acid determinations were made. Rasped beet pulp treated with 70% (by volume) isopropyl alcohol was found to offer a simple and convenient means of preparing extracts of beet tissue. The fraction of the total glutamic acid separated by this procedure corresponds closely to that obtained in factory thin juice. The extract after evaporation and hydrolysis is assayed microbiologically for glutamic acid.

Extraction and Hydrolysis: 25 g. of freshly rasped pulp (frozen pulp is also satisfactory) is washed into a flask with about 50 ml. of distilled water, 175 ml. of 99% isopropanol added, and the final volume adjusted with water to 250 ml. The mixture is shaken several times and allowed to stand overnight, the volume again adjusted to 250 ml. if necessary, and filtered. A 150-ml. aliquot of the filtrate is evaporated almost to dryness in vacuo. Any material sprayed on the walls of the flask or into the distilling trap is washed down into the flask with 25 ml. of distilled water, and the solution is hydrolyzed for two hours in a boiling water bath with 5.9 g. of $Ba(OH)_2.8\ H_2O$. The mixture is seeded with a pinch of barium saccharate to facilitate the precipitation of insoluble saccharate. The deposition of sugar as barium saccharate during hydrolysis minimizes destruction of glutamic acid due to browning reactions.

After hydrolysis is complete, the barium saccharate is redissolved by acidification with concentrated hydrochloric acid, and mixture adjusted with sodium hydroxide to pH 6.3 and diluted with water to a final volume of 50 ml. Barium salts which precipitate on standing in the cold are filtered off prior to microbiological assay.

Microbiological Assay: The procedure is a modification of that of Hac, Snell and Williams (1)[2] and is dependent upon the fact that the microorganism LACTOBACILLUS ARABINOSUS 17-5 requires for growth either L-glutamic acid or glutamine together with various other amino acids and vitamins. Pyrrolidonecarboxylic acid *cannot* be utilized by this organism.

The general procedures and basal medium described by Hac, Long, and Blish (2) have been modified slightly to handle barium hydrolysates of beet pulp extracts. In order to precipitate the barium salts introduced with the sample, additional ammonium sulfate is added to the basal medium used for both the standard glutamic acid curve and the samples being analyzed. Routinely, 0.035 g. of ammonium sulfate per assay tube (5 ml. final volume) is added. This amount is sufficient to prevent any inhibition of growth which would result from the barium introduced in a sample of 0.6 ml. or less. If the glutamic acid content of the hydrolysate is so low (less

[2] Numbers in parentheses refer to literature cited.

than 0.01%) that a larger volume of sample is required, additional ammonium sulfate must be added to precipitate the barium introduced: 0.1 g. for a maximum sample of 2.5 ml.

The standard glutamic acid curve is prepared in triplicate using 51 tubes over the assay range of 0.03 to 0.3 mg. of glutamic acid. Final values reported are the average of 6 determinations; duplicate tubes at 3 levels of concentration. Since the glutamic acid content of beet pulp may range from less than 0.01%, to more than 1.0%, we have found it advantageous to obtain

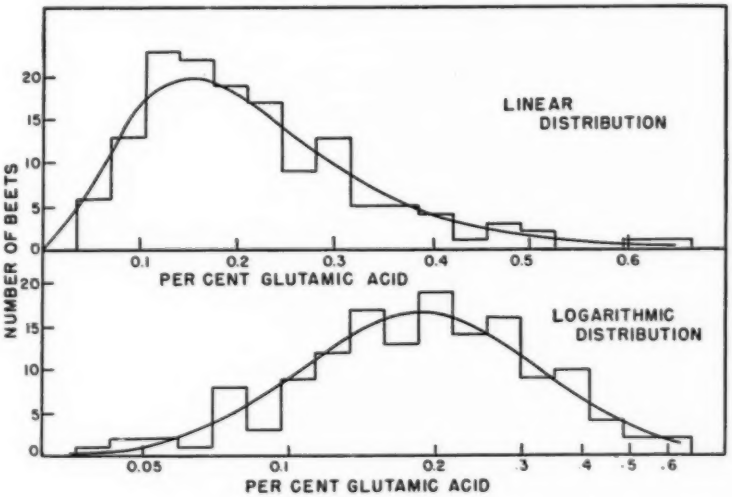

Figure 1. Distribution Curves of Glutamic Acid Concentration of Individual Beets.

an estimate of the concentration from a preliminary determination using only a single tube for assay. In this way, it is possible to select sample amounts for the final determination so that they will all fall within the most reliable portion of the standard curve, and to obtain a four fold overall spread between the 3 levels of concentration measured. That is, sample volumes would be selected to contain 0.05, 0.1 and 0.2, or 0.06, 0.12 and 0.24 mg. of glutamic acid. By this procedure, inhibitors or activators which sometimes cause difficulty in beet materials can be readily detected.

Field Techniques: Experiments designed to study responses of sugar and weight in beets are ordinarily readily adaptable to glutamic acid measurements. The chief difficulty is the wide individual variation in glutamic acid. The coefficient of variation for this substance is about twice as large as that of root weight and about five times as large as sugar content. Ideally, all beets of the plot should be included in the sample, the practical minimum

(using 5 to 8 replications) is a *forty* beet sample. Since this is about comparable to a two beet sample for sugar determinations, only very large effects can be measured. Fortunately, at least in nitrogen fertilizer experiments, the magnitude of the response is similarly inflated, so that results comparable in significance to those of sugar may be obtained.

Treatment of Data: A typical example of the distribution of glutamic acid values found in *individual* beets from the same field is shown in Fig. 1. When the glutamic acid values are grouped on a linear scale, the distribution curve is found to be considerably more pointed than a normal curve of

Table 1.—Effect of Fertilization on a Field of Sugar Beets Grown in Fort Collins, Colorado in 1947.

Treatment	Tons Beets per Acre	Tons Sugar per Acre	Percent Sucrose	Percent Glutamic Acid
Manure	16.6	2.36	14.1	0.06
P	12.1	1.72	14.2	.06
NP	18.6	2.40	12.8	.22
NPK	19.6	2.50	12.8	.25
None	8.2	1.09	13.4	.07
L.S.D. (19:1)	1.7	0.35	0.8	76%

Arrangement: Latin square
Planted: April 3, 1947
Harvested: Middle of October
Samples: 60 Beets per plot

error, and an abnormally large number of the glutamic acid values are found to be higher than the most frequent value (i.e., the curve is skewed, positively). Starting with 0% glutamic acid, the curve may be fitted accurately with a Pearson Type III curve (variance is proportional to the mean), but not with the normal frequency curve required for the analysis of variance. However, when the same data are graphed on a logarithmic scale, the distribution gives a good fit to the normal.

Transformation to logarithms is also desirable in composite samples containing up to at least 40 beets. A possible exception to its use may be in data where nearly all glutamic acid values are over 0.3%. In such high content beets, the glutamic acid distribution curve becomes nearly normal. However, in most cases it is desirable to convert glutamic acid data to their logarithms before carrying out the analysis of variance. Consequently, results are expressed as geometric means unless otherwise noted, and differences required for significance expressed as percentage increases over the lower of the two values compared.

Fertilizer Experiments

Two field experiments, one in Colorado, the other in California, have been selected to demonstrate the effect of fertilizer upon yield, sugar and glutamic acid content of sugar beets. The *Colorado test* is taken from an experiment on restoring fertility to recently leveled land at Fort Collins conducted by Whitney, Robertson and Gardner in 1947 (3). Their results on sugar and yield were reported at the 1948 meeting of the Society. Residual samples of pulp used for their sugar analyses were frozen at the time of harvest and shipped to Woodland where they were held in frozen storage until April, 1948, when glutamic acid analyses were made.

In this experiment, fertilizer was applied at the following rates:

Treatment	Manure	P	NP	NPK	None
Lbs. N/Acre	430	.....	430	430	.....
Lbs. P_2O_5/Acre	220	220	220	220	.....
Lbs. K_20/Acre	560	.....	.....	560	.....

The manure was applied in the spring of 1946 while the three commercial fertilizer treatments were divided equally between spring and fall applications. Very significant responses in sugar and tonnage to both nitrogen and phosphate were obtained by Whitney, et al., in the beets grown in this

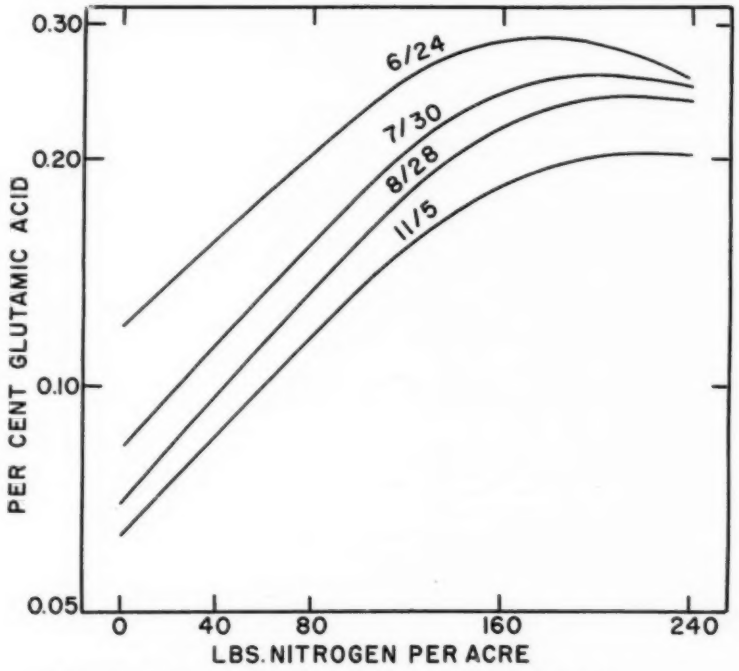

Figure 2. Glutamic Acid Response to Nitrogen Fertilization.
Glutamic acid content of sugar beets at various levels of nitrogen fertilizer at harvest (November 5) compared with three earlier sampling dates.

field in 1947. Those are compared with the glutamic acid responses in Table 1.

Beets grown with phosphate or with manure had built up no more glutamic acid than the highly nitrogen deficient untreated beets. Application of phosphate evidently increased the nitrogen foraging ability of the crop sufficiently to make possible nearly 4 tons of extra root growth, but nitrogen remained a seriously limiting factor. No response to potash was observed. The glutamic acid data indicate that the same situation holds

true for the manure treatment—the beets acquired sufficient nitrogen from the manure for 8 tons additional growth, but were still limited by nitrogen supply. This suggests that a combination of the manure treatment with additional commercial nitrogen would have given higher yields of sugar than any treatment actually used.

The treatments including commercial nitrogen fertilizer (ammonium nitrate) showed an average increase of 260% in glutamic acid content over treatments without nitrogen; a highly significant effect. Individual plots without nitrogen ranged from 0.03 to 0.19% and those with nitrogen from 0.14 to 0.35% glutamic acid. Comparison with the California data (which follows) indicates that most of the nitrogen response was attributable to the fall treatment, residual effects of the spring treatment of the previous year being only about sufficient to make up for nitrogen losses before the beets were planted.

The *California test* was a cooperative study with California Packing Corporation, the grower. Sugar determinations were made by Spreckels Sugar Company, glutamic acid by our laboratory, and petiole nitrate by Dr. Albert

Table 2.—Effects of Fertilization on a Field of Sugar Beets Grown in Yolo, California, in 1947.

Treatment Lbs. N/Acre	Percent Stand	Tons Beets per Acre	Percent Sucrose	Tons Sugar per Acre	Percent Glutamic Acid
0	62	13.9	16.0	2.21	0.064
40	60	15.8	16.2	2.56	.082
80	54	17.5	15.4	2.69	.114
160	54	19.2	14.4	2.76	.193
240	65	20.6	14.5	2.98	.192
240 + P	56	20.0	14.8	2.96	.215
L.S.D. (19:1)	10	1.34	0.5	0.27	24%

Ulrich of the University of California. The results of the petiole tests and a detailed description of the field have been reported elsewhere (4). The field of almost 10 acres was located a few miles north of Woodland. The design, a complete randomized block, consisted of 6 replications of the 6 treatments used; 0, 40, 80, 160, 240 pounds of N applied as ammonium nitrate, and 240 pounds of N + 200 pounds P_2O_5 (as treble superphosphate) per acre. Each plot was 12 rows wide and 600 feet long. U. S. No. 33 seed was flat planted on March 24, 1947. The field was thinned May 6, fertilizer applied as a side dressing May 7 and 8, and the beets hand harvested November 11.

Yields were taken from the entire harvest area of 12 rows per plot, but sugar and glutamic acid measurements were obtained from 40 beets sampled from the 4 center rows of each plot a few days prior to harvest. The weights of these samples were in general agreement with the harvest yields.

The results at harvest given in Table 2 showed a pronounced nitrogen deficiency in this field. Beet yield increased regularly to the highest nitrogen level tested, but the data on gross sugar production indicated that in terms of profitable return to the grower, little was gained by applications of fertilizer in excess of 80 pounds of nitrogen per acre. Phosphate treatment

was ineffective in all variables tested, and may be considered a duplicate of the 240-pound nitrogen treatment. Ulrich stated that the petiole test indicated that "the phosphate failed to get into the beets."

All analytical data on samples seem to point to a sharp cessation of response to nitrogen over 160 pounds per acre. This effect has not been duplicated in any of our other fields and appears to be caused largely by the chance occurrence of unusually fertile 160-pound plots and infertile 240-pound plots, at least in the 4 row sampling areas. On the basis of our other studies, nitrogen responses far beyond the 0.2% glutamic acid and 14.4% sugar obtained in this field should be possible.

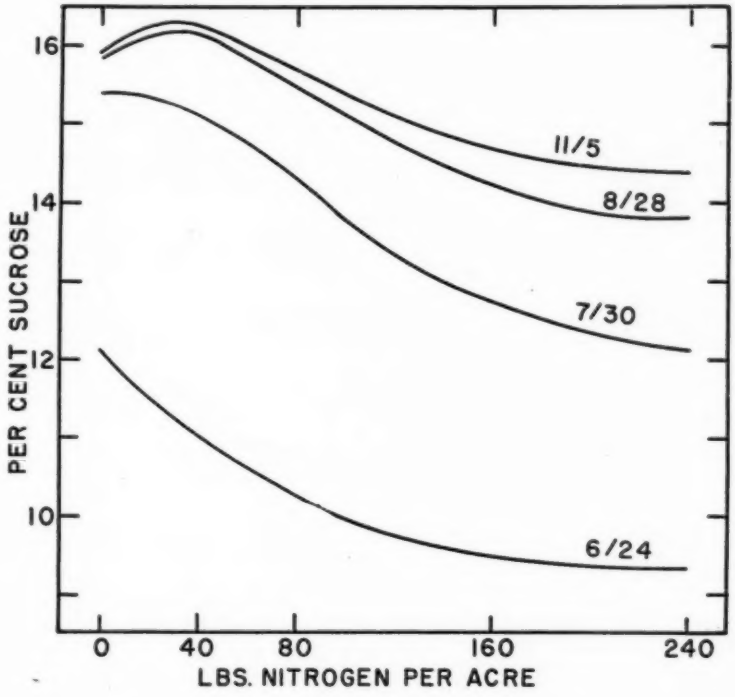

Figure 3. Effect of Nitrogen Fertilizer upon Sucrose Concentration. Effect of nitrogen fertilizer on percent sucrose at harvest (November 5) compared with three earlier sampling dates.

Nitrogen caused a rapid increase in glutamic acid content up to 160 pounds of nitrogen per acre. The average slope of the best straight line regression on nitrogen level using a logarithmic scale for glutamic acid indicated an increase of 115% for any 160-pound increment of nitrogen. The advantage of using the logarithmic scale is indicated by the range of values

of individual plots around the mean: the control treatments ranging 0.03% around a mean glutamic acid of 0.064% while the 240 plots ranged 0.200% around a mean of 0.192%. Use of logarithms gives a homogeneous variance for all treatments.

Function of Glutamic Acid

In order to obtain better insight into the function of glutamic acid (or its precursor) in the growth of the beet, three additional samplings were made in this field prior to harvest, the first on June 24, three months after

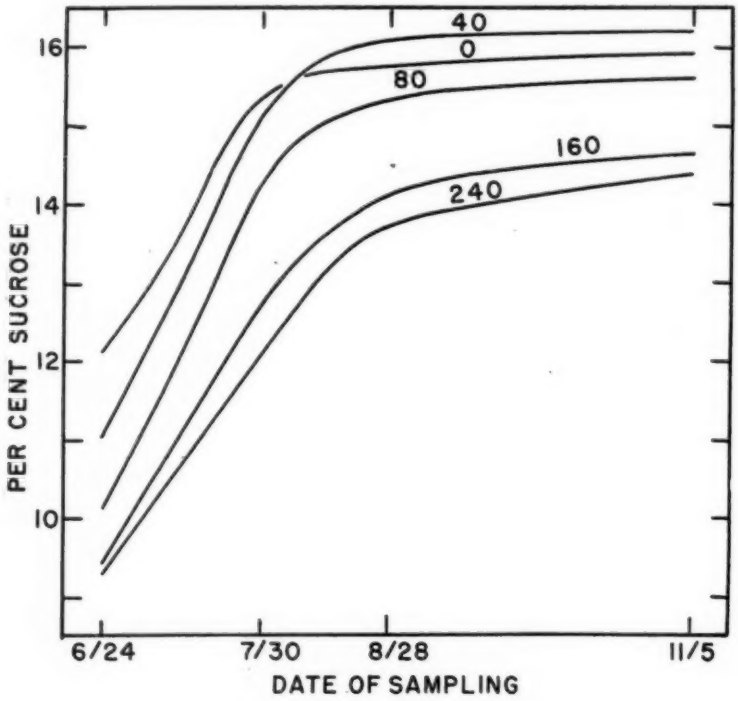

Figure 4. Effect of Age of Beet upon Sucrose Concentration at Different Fertilizer Levels.

Increase in percent sucrose with increasing age of the beet at different levels of nitrogen fertilization in a field in Yolo County, California in 1947.

planting; the second on July 30; and the third on August 28, roughly 2 months before harvest. The results from the 6 replications of each treatment were averaged and the best curves depicting the effects of nitrogen fertilizer on sugar and glutamic acid are shown in Figs. 2-5.

The response of glutamic acid to fertilizer nitrogen observed at harvest

was corroborated by the three earlier samplings (Fig. 2), but the flatter curve of the first sampling date, June 24, indicates a less pronounced effect of nitrogen level in young beets (average weight 12 ounces). The average response at 160 pounds of nitrogen was 56% as compared with 115% at harvest. This increase of slope with age is quite significant. The abnormal lack of response between 160 and 240 pounds of nitrogen in this field makes it difficult to be certain of the effect of age upon response at higher nitrogen

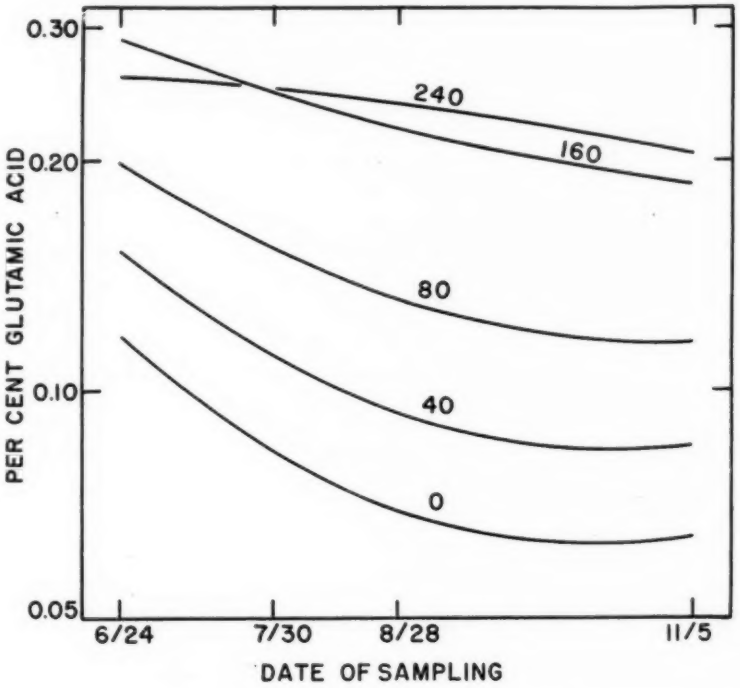

Figure 5. Effect of Age of Beet upon Glutamic Acid Concentration at Different Levels of Nitrogen Fertilizer.

levels even though a greater tendency toward straight line response (less curvature) with increasing age is evident in Fig. 2.

Comparable curves indicating the effect of fertilizer nitrogen in decreasing the sucrose percentage at the various sampling dates are described in Fig. 3. Here, the maximum effect was obtained at the July 30 sampling, but the relative change is much less pronounced than those at any date for glutamic acid.

Beet yields on the first sampling date were not affected greatly by nitrogen

fertilization, but during July and August marked differences in treatments became evident. Apparently, very little growth occurred during September and October, because the November yields were not appreciably different from those at the end of August. Actually, in the untreated plot there appeared to be a loss. These beets had practically no tops left at harvest and contained less sugar than the beets of the 40-pound nitrogen treatment, which may confirm the tendency to maximum sugar at the 40-pound treatment even though it is not statistically significant.

The expected rapid rise in sugar with increasing age of the beet, depicted more clearly in Fig. 4, shows a sharp levelling off during September when growth had practically ceased. Sugar increases with age much more rapidly than glutamic acid decreases. The cessation of growth during September was evidently not caused by lack of nitrogen except possibly in the unfertilized plots.

The regular decrease in glutamic acid with age is shown in Fig. 5. The change is small (averaging about 10% per month) and nearly disappears at the lower N levels during the two months prior to harvest. Thus, harvest date has little effect on experiments on glutamic acid. The average decrease with age is greater the lower the nitrogen fertilizer usage, but the percentage decrease with age, measured by the curvature of the line, is also greater. In fact, at the 240-pound level, the curve bends in the opposite direction.

It seems possible that the nitrogen required in formation of beet protein could be stored conveniently as the glutamic acid precursor, glutamine. Thus, under limited supplies of nitrogen, the glutamine content of young, rapidly growing beets would be expected to decrease more rapidly than would be the case with more mature beets. Lack of photosynthetic power to reduce nitrates as well as rapid growth rate probably limits the glutamine content of young beets at a relatively low value.

The view of glutamine as a storage material is substantiated by the results obtained in an experiment in which the glutamic acid content of beets which had gone to seed was compared with that of non-bolters in the same field. Individual analyses were made of 48 bolters found in a quarter-acre area in a field of U. S. No. 33 beets. A control beet with roughly the same competition was selected near each bolter and analyses made on composites of 8 beets each. Results were as follows:

	Non-Bolters	*Bolters*
Mean Root Wt. in Lbs.	2.61	1.42
Weighted Mean Sugar %	16.9	13.7
Median Glutamic Acid %	0.17	0.007

Seven of the bolters, including all those over three pounds in weight, were in the usual range of glutamic acid; that is, over 0.04%. Seven others were at 0.003% glutamic acid, the lowest limit at which the analytical method can be used. Apparently in most cases the demands of the beet for nitrogen used in protein formation for growth of the seed stalk had exhausted completely the supply of glutamic acid in the root. Further studies on the function of glutamic acid will be reported later.

Summary

Methods for measurement of potential glutamic acid in sugar beets have been described and applied to a study of the effects of fertilization. In a California experiment, fertilizer nitrogen caused a logarithmic increase in the glutamic acid of beets, more than doubling it by an increment of 160 pounds of nitrogen between 0 and 240 pounds of nitrogen per acre without impairment of sugar tonnage. A similar response was obtained in Colorado from commercial fertilizer, but not from manure. The addition of phosphate had no effect on glutamic acid.

Glutamic acid decreased with increasing age of the beet, but the decrease during the harvestable period was only 12%. Beets which had gone to seed contained much less glutamic acid than non-bolters from the same field. Glutamine, the probable precursor of glutamic acid, appears to be one of the major components of the storage nitrogen of the beet, and a study of this material offers information regarding the nitrogen status of the crop as well as its potential value as a by-product material.

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Sand Culture Experiments With Sugar Beets

ALBERT C. WALKER, M. LOUISA LONG, AND LUCILE R. HAC[1]

Glutamine is the probable precursor of glutamic acid in sugar beets, and the amount present in the beet is dependent largely upon the available soil nitrogen. It has been possible to measure the effects of various amounts of nitrogen fertilizer upon the glutamic acid content of beets grown in the field and to obtain a fairly accurate evaluation of this response (1, 2).[2] However, due to the extreme variability found in the glutamic acid of individual beets grown in the same field, prohibitive numbers of beets are required for exact quantitative measurements. A substantial reduction in this variation was sought in order that reasonably sized experiments could be undertaken to study factors altering the response to fertilizers.

Beets grown under controlled nutrient conditions seemed the best approach to this problem. Preliminary experiments with growth in pots of hand mixed soil with limiting supplies of nutrient or growth in solution culture held little promise. Growth in sand with complete chemical nutrient solutions have been highly satisfactory, however, and the results of a two-year study with this type of culture will be reported here. In these studies, the nutrient environment was maintained as constant as possible by frequent applications of freshly prepared solutions used in sufficient amounts at each application to flush out any old nutrient present. This procedure should also limit any effect of nitrifying bacteria on the nutrient.

The purpose of the first year's study, which was carried out with commercial seed, variety U. S. No. 33, was to determine the effect of a constant nutritional environment upon sugar beets grown in pots of sand outdoors in full sunlight during the regular beet growing season in California. The same nutrient solutions were used during the entire growth period. The effects of varying amounts and concentrations of nitrogen upon weight, sugar and glutamic acid were determined.

The second year, seed from two strongly contrasting inbred lines of beets was used instead of a commercial variety. The experiment was set up in a factorial design to study the effects of: 1, two levels of nitrogen; 2, ammonia vs. nitrate; and 3, high sodium vs. high potash treatments. At harvest, individual root and top weights were obtained and analyses were carried out for sugar, glutamic acid (1), Na, K (3), Ca (4), Mg (5), Mn (6), and soluble inorganic salts.

Procedure

The beets were grown in 12-inch unglazed flower pots containing 34 pounds of 20-mesh sand. The sand used retained about 2,000 ml. of nutrient and 1,900 cc. of free air space after 20 minutes drainage. Regular applications of 4.5 liters of freshly prepared nutrient solution were carried out during the entire growth period by flooding the sand surface. Each of the

[1] Research Division International Minerals & Chemical Corporation, Woodland, California.
[2] Numbers in parentheses refer to literature cited.

various nutrients used was prepared by mixing one volume of each of three stock solutions with 1,200 volumes of well water. The required amounts of each stock solution were measured out accurately well in advance of actual use.

The stock solutions were prepared to contain the desired amount of nutrient in a minimum volume of stable solution. Their compositions are shown in Tables 1 and 2.

Solution 1 contains sufficient sulfuric acid to produce a pH of 6.1 in the final dilute nutrient, all of the sodium over 5.2 mM in the final nutrient, and the trace heavy metals and magnesium. The well water used in these experiments provided sufficient magnesium.

Solution 2 provides a large excess of calcium and chloride so that alterations may be made in ammonium and nitrate without great effect on the former nutrients.

Solution 3 provides high levels of phosphate, potassium or sodium, and the trace anions. The final nutrients are saturated with iron phosphate and supersaturated with dicalcium phosphate. Their composition in regard to individual nutrients is shown in Table 2, together with the known constituents of the well water used in these experiments.

The seeds were planted 6 to 8 per pot about May first and thinned gradually to one beet per pot about 7 weeks after planting. Germination was excellent, but some trouble was encountered due to seedling disease and to burning of the young leaves at the sand surface during the hot weather. Harvests were made the middle of November.

1948 Experiment

This introductory experiment, to study sand culture techniques and to determine the effects of both amount of nitrogen in the nutrient solutions and rate of nutrient application, tested the following four treaments:

Treatment	Nutrient	Applications per day	Conc. of N mM/L	Amt. of N Est. mM/day	Number of Beets Treated
1	I	2	1	4	7
2	II	2	2	8	7
3	II	1	2	4	6
4	III	1	4	8	6

At the alternate times when treatments 3 and 4 were not applied, sufficient well water adjusted to pH 6.1 with sulfuric acid was used to barely saturate the sand. Watering or nutrient application at least twice daily was found to be necessary to prevent wilting.

Effects of Amount of Nitrogen: At both levels of nitrogen used, the young beets (6 weeks after planting) showed symptoms of nitrogen deficiency. They contained only about 0.1% glutamic acid, the leaves were yellowish, and significant differences in leaf length were evident between the beets grown at the two amounts of nitrogen furnished. The difference disappeared during the subsequent rapid growth period, and the leaves slowly became dark green and remained green.

At harvest, corings of each beet were analyzed for sucrose and glutamic acid (1). The only significant results obtained were those assignable to

Table 1.—Stock Solutions[1]

Nutrient	1948 1	1948 2	1948 3	1948 X	1949 A	1949 B	1949 C	1949 D	1949 E	1949 F	1949 G	1949 H
Solution 1												
H_2SO_4	191.5	191.5	191.5	191.5	191.5	191.5	131.0	131.0	131.0	131.0	191.5	191.5
Metals[2]	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3
$Na_2SO_4.10H_2O$	0	0	0	0	0	0	348	348	348	348	0	0
Solution 2												
$CaCl_2.2H_2O$	529	529	529[3]	529	529	529	529	529	529	529	529[4]	529
NH_4Cl	0	0	0	0	0	48.2	48.2	0	0	96.3	96.3	0
$Ca(NO_3)_2.4H_2O$	0	0	0	850	70.8	0	0	70.8	141.7	0	0	141.7
NH_4NO_3	50.1	100.3	200.6	200.6	0	0	0	0	0	0	0	0
Solution 3												
$K_2HPO_4.3H_2O$	822	822	822	822	822	822	0	0	0	0	822	822
KH_2PO_4	163	163	163	163	163	163	0	0	0	0	163	163
$NaH_2PO_4.H_2O$	0	0	0	0	0	0	464	464	464	464	0	0
$Na_2HPO_4.12H_2O$	0	0	0	0	0	0	516	516	516	516	0	0
H_3BO_3	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22
$(NH_4)_6Mb_7O_{24}.4H_2O$	0	0	0	.022	.022	.022	.022	.022	.022	.022	.022	.022

[1] H_2SO_4 and Metals in ml/L, all others in gm/L

[2] Metals $FeSO_4$ 54.8, $AlCl_3.6H_2O$ 32.2, ZnO .448, $CuCl_2.2H_2O$ 1.94, $MnSO_4.2H_2O$ 27.6 gm/L and H_2SO_4 10 ml/L

[3] This Solution saturated at 15°C

[4] This Solution saturated at 45°C

amount of nitrogen furnished as shown as shown in the following table:

Amount of N mM per day	Root Wt. Lbs.	Top Wt. Lbs.	Sucrose Percent	Glutamic Acid Percent
4	4.09	1.20	15.4	0.50
8	5.15	1.52	13.5	0.72
L.S.D. 5%	1.02	(0.44)	1.2	0.15

Effect of Rate of Application of N: Rate of nutrient application had no appreciable effect in itself or in altering the response to amount of nitrogen available. Twice daily application appeared to be preferable; the results were more uniform, and the time required for application of nutrient was actually less than that necessary for careful watering. The quality of the beets obtained indicates that a substantial fraction of all nitrogen available was absorbed by the beets.

Table 2.—Concentration of Nutrients

Millimols per Liter of Final Solutions

Nutrient	1	2	3	X	A	B	C	D	E	F	G	H	Well water
Ca	3	3	3	3	3.25	3	3	3.25	3.5	3	3	3.5	1.5
Cl	6	6	6	0	6	7	7	6	6	8	8	6	2.6
NH_4	0.5	1	2	2	0	.75	.75	0	0	1.5	1.5	0	
NO_3	0.5	1	2	8	.5	0	0	.5	1	0	0	1	
K	7	7	7	7	7	7	0	0	0	0	7	7	
Na	0	0	0	0	0	0	7	7	7	7	0	0	
SO_4	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	0.6
PO_4	4	4	4	4	4	4	4	4	4	4	4	4	
Mg	0	0	0	0	0	0	0	0	0	0	0	0	1.3

Parts per million Final Solution

Fe	Al	Mn	Cu	Zn	B	Mo
.5	.1	.25	.02	.01	.3	.01

Comparison with Field Grown Beets: The large root weight and extraordinary glutamic acid content of these beets grown in sand culture indicates that except during very early growth even the lower amount of nitrogen furnished was much greater than that which would produce the average type of sugar beet in the field. On the other hand, sucrose was very high for such high nitrogen beets, indicating that the primary difference from field-grown beets was in improvement of the storage potential (2) rather than in the amount of available nitrogen.

In further contrast to field-grown beets, those beets growing at a given and constant level of nitrogen showed a considerable negative correlation ($r = -0.474$) between glutamic acid and root weight, which provides strong direct evidence that glutamine acts as storage nitrogen. The magnitude of the response is such that a 10% increase in size under constant nitrogen nutrient results in a *decrease* of 0.032% glutamic acid, or 5% of the average glutamic acid. This variation in size reflects a faster growth of the beets chiefly attributable to variations in vigor. Such growth involves protein formation at the expense of the stored glutamine.

On the other hand, a 10% increase in size resulting from an increased nitrogen supply is accompanied by an *increase* of 0.103% glutamic acid, or 17% of the average glutamic acid. This increase in glutamic acid must represent a net change after using some of the absorbed nitrogen for growth.

At a given nitrogen level, there was no correlation between sucrose and either weight or glutamic acid.

The highly unusual nature of these beets makes it impossible to draw definite conclusions as to reduction of variability resulting from the experimental environment. Glutamic acid shows a coefficient of variation of 30%, which is reduced to 26% when the relationship to beet weight is taken into account. This is an enormous improvement in reproducibility over the usual value of 100% for field beets. However, a considerable part of the decrease in variability could be caused by the high N level rather than by constancy of environment.

Table 3.—Comparison of Leaf and Storage Type Beets Grown in Sand Culture 1949.

Variety	Leaf Type	Storage Type	L.S.D.
Root Wt. in Pounds	0.68	1.18	0.20
Top Wt. in Pounds	.66	.16	.15
Percent Sucrose	11.6	15.6	1.2
Percent Glutamic Acid	0.22	0.88	0.07
Percent Soluble Inorganic Salts	1.26	.59	.11
Percent Sodium	.102	.024	.031
Percent Potassium	.40	.18	.05
Percent Magnesium	.059	.050	.010
Percent Calcium	.048	.036	.012
ppm. Manganese	31	20	6

Root weights were obviously much more constant than for field beets, especially the lack of very large and small beets. The weights had a coefficient of variation of 31%, in contrast to field beets with 50% or more. Much of this improvement could be due also to high nitrogen level, or to lack of competition. Sucrose (coefficient of variation of 10%) showed no improvement over field beets.

1949 Experiment

This experiment was again concerned with the effects of amount of available nitrogen. In addition, differences in response to type of nitrogen (ammonium salts vs. nitrate), the effects of high potash in contrast to high sodium nutrient, and the differences between two inbred strains of beets were investigated.

Both varieties of beets used were in the seventh generation of inbreeding, chiefly by selfing[3]. The parent generations of these beets had shown characteristically different top growth and root shape, and both varieties appeared to be nearly homozygous in these conformations. Analyses had indicated highly significant differences between the varieties in sucrose and glutamic acid content. For purposes of identification here, the two varieties have been designated as "leaf type" and "storage type." The leaf type variety was characterized by heavy, upright leaf growth. The leaves were

[3] Seed was obtained through the kindness of Mr. G. W. Deming, Agronomist, U.S.D.A., at Fort Collins, Colorado.

relatively large, long, noncrinkled, and shiny bright green in color. The roots were tapering, low in sucrose and glutamic acid content. The storage type variety had less heavy, more open, low, flat top growth. The petioles were short and thin; the leaves only slightly longer than wide, slightly crinkled and medium dark, dull green in color. The roots were rounded in shape, high in sucrose and glutamic acid content.

Sixteen pots of each variety (planted alternately in a single row) were grown 9 weeks on high nitrogen nutrient, solution X. At the final thinning, the beets appeared to have an excellent nitrogen status. The nitrogen in the nutrient was reduced at this time, and four pots of each variety received solutions A, B, G, and H. At 11 weeks of age, sodium was substituted for potash in half of the beets at each nitrogen level, making eight nutrient treatments A to H (see Table 1), which were used throughout the remainder of the experiment.

Table 4.—Comparison of High Potash vs. High Sodium Treatments.

Treatment	Potash	Sodium	L.S.D.
Percent Sodium	0.017	0.109	0.031
Percent Potassium	.37	.85	.11
Percent Magnesium	.064	.045	.011
Persent Soluble Inorganic Salts	1.01	.85	.11

Growth of many of the leaf type beets was impaired seriously by attacks of the sugar beet crown-borer (*Hulstia undulatella*, Clemens). The crown-borer was finally controlled by an occasional application of 0.3 gm. of 50% DDT suspended in the nutrient solution. The leaf type variety was also selectively but not seriously attacked by aphids, diabroticas, and caterpillars.

Effects of Variety: Definite differences between the leaf and storage type varieties are apparent from the average results at harvest given in Table 3. The lower root weight and higher Mg, Ca, and Mn contents (which are closely correlated with weight in the leaf type beets) were evidently caused by the selective insect damage. The larger top weight and potassium content of the leaf type variety were reached in spite of the damage, which tended to reduce them. Insect damage could have been responsible only in small part of the much higher sodium and inorganic salt and lower sucrose and glutamic acid content of these beets.

Effects of Sodium vs. Potash Treatments: Substitution of sodium for potash in the nutrient 11 weeks after planting produced the significant changes in Na, K, Mg, and soluble inorganic salts shown in Table 4. It also produced certain minor alterations in the larger nitrogen and ammonia effects on sucrose and glutamic acid. The decreases in Mg. and soluble inorganic salts noted were caused by the low potash supply—both measurements were in general closely correlated to the potassium content.

Variety of beet had considerable effect upon the changes produced by sodium nutrient. Inorganic composition was influenced by both nutrient

and genetics. Potassium and soluble inorganic salts show this effect relatively simply:

Variety	Leaf Type		Storage Type		
Treatment	Potash	Sodium	Potash	Sodium	L.S.D.
Percent K	0.55	.25	.20	.17	.06
Percent Soluble Inorg. Salts	1.41	1.12	.60	.58	.15

Thus the effects of genetics and nutrient upon percent K are much more than additive; one must be adequate for demonstration of the other. Variations in inorganic salt content follow variations in K content except in the sodium-treated leaf type beets. Effects on % Mg and % Ca somewhat similar to those on percent K are discussed with the ammonia effects.

Percent Na is higher in the leaf type beets and is increased by sodium in the nutrient as is percent K by potash in the nutrient, but the situation

Table 5.—Effect of Type and Level of Nitrogen.

	Treatment	Millimols Nitrogen per Day				
		2N[1]	3A	4N	6A	L.S.D.
Percent Sodium—Leaf Type	K	0.024	.026	.011	.020	.121
	Na	.057	.192	.190	.294	
Percent Sodium—Storage Type	K	.019	.014	.007	.012	.012
	Na	.028	.036	.044	.036	
Percent Glutamic Acid	K	.43	.46	.54	.72	.12
	Na	.42	.66	.47	.68	
Root Wt. in Pounds		.96	.84	.79	1.13	.28

[1] Nitrogen supplied as nitrate (N); as ammonium salts (A)

is further complicated by a strong stimulation by nitrogen level for sodium absorption in the presence of sufficient sodium in the nutrient (Table 5). This stimulation is nearly proportional to the nitrogen content independent of the form of nitrogen, and is much stronger in the leaf type beets.

In the absence of sufficient sodium in the nutrient, percent Na is affected quite differently. In this case, the higher Na of the leaf type beets is explainable by insect damage (the larger, less damaged beets had the same Na content as the storage type beets). Increase in nitrate lowers instead of raising the percent Na, while ammonia nitrogen has little effect. The leaf type beets appeared to have a much more extensive system of root hairs than the storage type beets. This may be the major explanation of the generally higher mineral uptake of this strain.

Effects of Nitrogen Level: Increasing the level of ammonia resulted in the expected rise in root weight, while increasing nitrate did not (Table 5). This is the only significant effect on root weight noted aside from that of variety or insect damage. An increase in weight with increasing nitrogen level could be expected in the leaf type beets with their low glutamic acid content, but the variations in weight (coef. var. 43%) caused by the insect damage may have masked the effect. In the storage type beets, the glutamic acid was so high even at the low level of nitrogen that no significant increase in weight could be expected, although the coefficient of variation in this variety was reduced to 19%. This reduction in variation over the commercial variety (31%) of the previous year is probably due to both homozygosity and the higher glutamic acid content.

Sucrose and top weight showed no consistent response to nutrient or significant differences in nutrient effects between the two varieties. Sucrose values in the leaf type beets were too low to give much of a nitrogen response; the coefficient of variation was 24%. In the storage type beets, the coefficient of variation was only 3% and the quite significant results are discussed later.

Glutamic acid was strongly increased by nitrogen level (Table 5). There was some tendency for this response to be greater for the leaf type beets, which had lower glutamic acid content.

Effects of Nitrates vs. Ammonium Salts: Beets grown with ammonia as the source of nitrogen in the presence of high sodium showed a considerably greater increase in glutamic acid than those grown at an equal nitrogen level on nitrate. In the potash-treated beets, the advantage of

Table 6.—Effect of Variety and Type and Level of Nitrogen

Variety / Treatment		Leaf Type		Storage Type		L.S.D.
		A[1]	N	A	N	
Percent Magnesium	K Treatment	0.072	.072	.070	.042	.022
	Na Treatment	.068	.031	.050	.033	
Percent Calcium		.059	.037	.035	.036	.015

[1] Nitrogen supplied as ammonium salts (A); as nitrate (N)

ammonia disappeared, the glutamic acid values being directly proportional to the nitrogen level. The absorption of ammonia appears to be repressed by high potash.

Ammonia also produced effects on Mg, Ca, and Mn content which appear to be independent of the ammonia concentration (Table 6). Ammonia is as effective as potash in raising magnesium content. Either would produce the maximum magnesium in the leaf type beets, but both are required to produce the maximum in the storage type beets. Beets receiving ammonia averaged 31 ppm Mn, those receiving nitrate 20 ppm; L.S.D. 6 ppm. Ammonia increased the calcium content only in the leaf type beets (Table 6).

Storage Type Beets: The generally greater accuracy obtained in the insect-resistant storage type beets elicited further information of considerable interest, although it may be applicable only to this extreme type of beet.

Potassium and root weight were highly correlated ($r = +0.83$). When the effects due to variations in root weight were eliminated by equalizing the root weights, the following significant effects of potash became evident: as in the leaf type beets, a definite increase in potassium content occurred on high potash nutrient which had been concealed by variations in root weights in the storage type beets. Moreover, there was considerably greater absorption of potassium in the beets receiving nitrate than in those receiving ammonia, and greater absorption at the higher nitrate level than at the low level. Increasing the ammonia, on the other hand, decreased the potassium content of the beets:

Millimols Nitrogen Per Day		Nitrate 2	Nitrate 4	Ammonia 3	Ammonia 6	L.S.D.
% Potassium (1-lb. roots)	K Treatment	0.20	.28	.18	.14	0.08
	Na Treatment	.07	.16	.13	.08	

Glutamic acid, after adjustment to equal root weights, gave the following comparable results:

Millimols Nitrogen Per Day		Nitrate 2	Nitrate 4	Ammonia 3	Ammonia 6	L.S.D.
% Glutamic Acid (1-lb. Roots)	K Treatment	0.76	.93	.83	.86	0.20
	Na Treatment	.68	.81	.97	.90	

The adjustment to equal weight removes most of the effect of increasing nitrogen level on glutamic acid, but brings out more strongly the tendency for a high potash level to stimulate nitrate absorption and to inhibit ammonia absorption as measured by the resulting glutamic acid values.

Sucrose in the storage type beets with their extraordinarily small tops decreased with increasing size of the root and increased with the increasing size of top ($R = 0.80$). Equalization of both root and top weights made even more significant the increase in sugar in the beets on the high K nutrient, and the rise in this increase with nitrogen level.

Millimols Nitrogen per Day		Nitrate 2	Nitrate 4	Ammonia 3	Ammonia 6	L.S.D.
Percent Sucrose (1 lb. root, 0.15 lb. top)	K Treatment	15.6	15.6	16.7	16.9	0.8
	Na Treatment	16.7	14.9	15.5	15.0	

Positive and nearly significant partial correlations of sucrose with both sodium (0.54) and soluble inorganic salts (0.69) at equal root and top weights indicate that the effect of potash is attributable to its greater power in raising the total salt content.

The effect of potash in raising the sugar content indicates the possibility of an economic optimum in salt content similar to that of nitrogen level. The extremely low inorganic salts in this line of inbreds probably contributed to the detection of this effect.

Smaller but also significant is the advantage in percent sucrose of ammonia over nitrate at equivalent nitrogen levels. This is particularly true for the high potash nutrient beets and may be attributed to the slowing of ammonia absorption by potash.

These beets also showed a high correlation (—0.76) between sucrose and glutamic acid. At equal levels of glutamic acid both ammonia, as opposed to nitrate, and potash, as opposed to sodium, raised the sucrose content quite significantly. This effect of ammonia in raising the storage potential (2) of beets may be explained plausibly on the basis of diversion of photosynthetic energy from nitrate reduction to sucrose formation.

The fraction of soil nitrogen actually available in the form of ammonia may thus be of considerable importance in estimating the proper nitrogen usage for a particular field.

Summary

Both commercial and inbred varieties of sugar beets have been grown very successfully in pots of sand with complete chemical nutrient solutions. The nutrient supply was maintained at the desired levels by frequent renewal with freshly prepared solutions. Amount, type, and rate of application of nitrogen, and high sodium vs. high potash nutrients, were studied. Their effects upon variety, root weight, sucrose, glutamic acid, Na, K, Mg, Ca, and Mn are discussed.

For commercial varieties 2 millimols of nitrate distributed in two applications per day is recommended after growth is well established. Younger beets require more nitrogen. The ammonium form of nitrogen seems to produce superior beets to nitrate, but for comparison with field beets, and possibly for more uniform results, nitrate is recommended.

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Time and Method of Fertilizer Application

BION TOLMAN AND STAFF[1]

During the past 5 years more than 350 field tests have been conducted with farmers to investigate the soil fertility problems in areas in which the Utah-Idaho Sugar company operates. These tests have investigated kind of fertilizer, rate of fertilizer, time of applying fertilizer, and methods of making the fertilizer placement. Some of the results of these tests have been given at previous meetings of the Sugar Beet Technologists.

In these previous reports it has been pointed out that fertilizer rates and ratios which supply from 60 to 80 pounds of nitrogen per acre and 45 to 60 pounds of P_2O_5 per acre have given the greatest yield increases. Consequently, we are now recommending the general use of 400 pounds per acre of such fertilizer mixtures as 14-13-0, 15-11-0, and 22-15-0. These three mixed fertilizers provide all the elasticity that is necessary in our area to fit the fertilizer recommendations to the needs of the various farms.

The present paper is a summary report of all the tests which furnish information relative to time and method of applying fertilizer in connection with sugar beet production.

AREA IN WHICH TESTS WERE CONDUCTED

Tests reported in this paper were conducted in Utah, Idaho, Washington, Montana, and South Dakota. All sugar beets grown in the areas under consideration are grown under irrigation. In some of the areas the first irrigation is applied prior to thinning, in some other areas beets are not irrigated until from two to three weeks following thinning.

EXPERIMENTAL RESULTS

Tests in 1946

Four tests were conducted in 1946 comparing the yield response from 300 and 600 pounds of 16-20-0 applied at the following periods: Planting time, thinning time, last cultivation (July 4 to 15), and split application (one-third of the fertilizer applied at each of the other 3 periods compared). Fertilizer applied at planting time was banded in 6 inches from the press-wheel mark with the same side-dresser which was used to apply the later treatments.

The results of these four tests are shown in Table 1. The average yield increase from 300 pounds of 16-20-0 was 1.93 tons per acre, and the average yield increase from 600 pounds of 16-20-0 was 2.93 tons per acre. Time of application had no significant effect on the fertilizer response. The highest average yield, 18.99 tons, was obtained from plots receiving fertilizer at planting time. The lowest average yield, 18.56 tons per acre, was obtained on the plots where the fertilizer was put on in split applications.

[1] Utah-Idaho Sugar Company.

Table 1.—Effect of Time of Application on the Yield Response Obtained from 300- and 600-pound applications of 16-20-0. Results are Averages of 4 Field Tests Conducted in Widely Separated Areas.**

Amount of Fertilizer Applied	Planting Time	Thinning Time	Last Cultivation	Split Application*	Combined Average Yield
300 Pounds of 16-20-0	18.14	18.47	18.42	18.06	18.27
600 Pounds of 16-20-0	19.84	19.29	19.09	18.87	19.27
Average Result	18.99	18.88	18.74	18.56	18.77
Yield of the Check	16.34	16.34	16.34	16.34	16.34

* Split application consisted of one-third of the amount of fertilizer applied at each of the 3 other periods compared.
** Each yield figure shown is the average of 8 replicated plots. Plots were 8-row strips. Entire strip harvested for yield data.

Tests in 1947

Following the tests in 1946, the question was raised as to whether the result would have been the same if the phosphate had been applied early in all cases and the nitrogen applied at later periods. Consequently, in the 1947 tests all phosphate was side-dressed at planting time. On one-half of the plots the nitrogen was also side-dressed at planting time; on the other half of the plots the nitrogen was side-dressed after thinning.

There was a total of 30 tests with 3 replicated plots of each treatment in each test. The various fertilizer treatments compared at each date of application are shown in Table 2.

The results of these tests confirm the results obtained in 1946. The average response of nitrogen over the checks was 2.56 tons per acre. The average yield increase from nitrogen plus phosphate was 2.93 tons per acre. Time of application had no significant effect on the response. The average yield for fertilizer banded in at planting time was 18.16, and the average yield for fertilizer side-dressed after thinning was 18.17 tons per acre.

Table 2.—Yield Response Obtained from Various Combinations of Nitrogen and Phosphate, Comparing also the Effect of Adding the Nitrogen at Planting Compared to Side-dressing after Thinning.

Fertilizer Treatments Compared	Nitrogen Banded in at Planting Time	Nitrogen Side-dressed After Thinning***	Combined Averages
1. Check (No fertilizer treatment)	15.97	15.97	15.97
2. 200 pounds of 32-0-0 (ammonium nitrate)	18.16	18.42	18.29
3. 400 pounds of 16-20-0*	18.53	18.76	18.65
4. 400 pounds of 32-0-0 (ammonium nitrate)	18.84	18.72	18.78
5. 600 pounds of 22-14-0**	19.29	19.00	19.15
Combined Averages	18.16	18.17	18.17

* 200 pounds of ammonium nitrate plus 200 pounds of treble superphosphate
** 400 pounds of ammonium nitrate plus 200 pounds of treble superphosphate
*** All phosphate was applied in bands 4 inches deep and 6 inches from presswheel mark at planting time. Nitrogen was side-dressed after thinning on this set of treatments.
All figures shown in the above table are averages of 30 field plots with 3 replicated plots of each treatment in each plot. Plots were 8 to 12 row strips. Entire strip harvested for yield data.)

FALL VERSUS SPRING APPLICATIONS

The fact that all prior tests had indicated that fertilizer might be put on in one heavy pre-planting application raised the question as to how far ahead of planting this application might be made. In view of the fact that

it would be advantageous to lengthen out this period even to the fall before, if possible, tests were set up to measure fertilizer response from fall as compared to spring applications. The complete set of treatments compared and the results of the tests are shown in Table 3.

It is evident from the data in this table that banding fertilizer into the seedbed in the fall of the year gave just as good results as did spring applications.

In areas of low winter moisture, such as is found in the areas where these tests were conducted, there is no apparent loss of fertilizer during the winter months.

Table 3.—Comparison of the Yield Response from Fertilizer Applied to the Seedbed in the Fall as Compared to Spring. All Fertilizer was Banded into the Seedbed about 4 inches Deep.

Kind and Amount of Fertilizer Applied Per Acre	Applications Made in the Fall	Applications Made in the Spring	Combined Averages
Check (Unfertilized plots)	16.89	16.89	16.89
200 pounds of 32-0-0 (ammonium nitrate)	18.95	18.33	18.64
400 pounds of 32-0-0	19.78	19.00	19.39
400 pounds of 16-20-0*	19.21	19.01	19.11
600 pounds of 22-15-0**	20.05	19.68	19.87
Combined Averages	19.02	18.58	18.80
Number of Replicated Plots of Each Treatment	10	10	20

Note: The above results included tests in Washington, Montana and South Dakota.
* 200 pounds of ammonium nitrate plus 200 pounds of treble superphosphate
** 400 pounds of ammonium nitrate plus 200 pounds of treble superphosphate

Tests in 1948 and 1949

In 1948 and 1949 tests which were designed to give further data on the effect of time and method of fertilizer application were conducted in all areas in which the Company operates. The first group of these tests was designed to compare the effect of banding fertilizer into the seedbed before planting with broadcasting fertilizer and working it into the surface of the seedbed, and both of these methods were compared with side-dressing after thinning. The complete set of treatments and the yield results obtained are shown in Table 4.

The average results of these two years of extensive tests indicate that it is just as well to band fertilizer into the seedbed before planting as to wait and side-dress after thinning. Fertilizer broadcast and worked into the surface of the seedbed was not as good as either of the banding treatments.

In connection with the banding in of fertilizer ahead of planting, one of the questions frequently asked is, "How important is depth of application, and what can the distance between bands of fertilizer be?" Field tests were conducted in which width between fertilizer bands as well as depth of fertilizer bands were investigated. The complete set of treatments and the results obtained are shown in Table 5.

When fertilizer was banded in 4 inches deep there was no advantage to having the fertilizer in bands 10 inches apart as compared to bands 20 inches apart. There was a consistent difference in favor of banding fertilizer

4 inches deep as compared to banding at a 2-inch depth. On a few plots there was some evidence of damage to the germinating seeds from the shallow pre-banded fertilizer. No damage was noted on plots where the banding was at the 4-inch depth.

In the above test a uniform rate of mixed fertilizer (400 pounds of 14-14-0) was used on all treatments. It was felt that it would be important to determine whether or not kind of fertilizer would have influence on the importance of depth of fertilizer application. Consequently, in a second series of tests sugar beets were side-dressed at varying depths with mixed fertilizer with nitrogen alone and with phosphate alone. The treatments

Table 4.—Effect on Yield Response on Sugar Beets of Commercial Fertilizer Applied by Different Methods. Uniform Application of 14-14-0 Mixed Fertilizer Applied on all Plots Except on Checks.

Method of Application Compared	Tests in 1948	Tests in 1949	Weighted Averages
Check (Unfertilized plot)	14.52	16.18	15.83
Side-dressed after Thinning	15.81	17.83	17.40
Broadcast and Worked into Surface of Seedbed	15.06	17.34	16.85
Banded into Seedbed before Planting	15.69	17.85	17.39
Fifty Percent Broadcast plus Fifty Percent Side-dressed	15.58	17.77	17.30
Total Number of Replicated Plots of each Treatment	16	59	75

were compared and the results obtained are shown in Table 6.

The results of these tests indicate that kind of fertilizer had very little influence on depth of placement. Broadcasting gave the lowest response (.92 tons per acre). Side-dressing 2 inches deep was next, with an increase over the check of 1.15 tons per acre, and side-dressing 4 inches deep gave the highest yield with an increase of 1.20 tons per acre.

Table 5.—Effect of Depth of Fertilizer Placement and Distance Between Bands of Fertilizer Banded into the Seedbed Before Planting—as Shown by Yield of Sugar Beets.

Depth Fertilizer Was Placed in Seedbed	Bands 20 inches Apart	Bands 10 inches Apart	Combined Averages
Fertilizer Applied 4 inches Deep	15.93	15.94	15.93
Fertilizer Applied 2 inches Deep	15.28	15.62	15.45
Combined Averages	15.62	15.78	15.70
Check (Unfertilized Plots)	14.52	14.52	14.52

Figures in Body of Table are Averages of 16 Replicated Plots.
Combined Averages are Averages of 32 Replicated Plots.

The difference between side-dressing 2 inches deep and 4 inches deep is not significant. The difference between side-dressing 4 inches deep as compared to side-dressing 2 inches deep was less than one might have expected, in view of the fact that banding fertilizer into the seedbed before planting at a depth of 4 inches gave consistently higher yields than did fertilizer banded to a depth of 2 inches. The difference between these two sets of tests in regard to the importance of depth of application may be explained as follows:

1. Deep side-dressing may prune off feeder roots of the growing beet. This is not a problem where fertilizer is banded before planting.

2. Deep side-dressing on some fields dried out the soil excessively, while on the before-planting applications the fields were harrowed after the fertilizer was applied.
3. On most fields where side-dressing shallow and deep were compared, the fields were irrigated soon after the fertilizer was applied.

Table 6.—Effect of Kind of Fertilizer on Method of Placement of Commercial Fertilizer as Shown by the Yield Response of Sugar Beets in Field Tests.

Methods of Fertilizer Application	400 pounds of 14-14-0 (56 lb. N. + 56 lb. P_2O_5	270 pounds Amm. Sulf. 56 lb. N.	130 pounds Treble Superphosphate (56 lb. P_2O_5)	Combined Averages
Broadcast and Worked into Soil Surface	14.58	14.28	14.04	14.30
Side-dressed 2 in. deep at Thinning Time	14.99	14.39	14.21	14.53
Side-dressed 4 in. deep at Thinning Time	14.97	14.45	14.32	14.58
Combined Averages	14.85	14.37	14.19	14.47
Check (Unfertilized Plots)	13.38	13.38	13.38	13.38

All Figures in Body of Table are Averages of 14 Replicated Plots.
All Combined Averages are Averages of 42 Replicated Plots.

DISCUSSION AND SUMMARY

The results of extensive field tests conducted over the past 5 years have shown quite conclusively that throughout the areas in which sugar beets are grown for the Utah-Idaho Sugar company mixed fertilizer supplying both nitrogen and phosphorus may be applied any time from the start of land preparation to after thinning. This makes the application of fertilizer to the sugar beet crop much easier than it would be if there were a short period during which it must be applied if maximum benefits were to be obtained.

Tests relative to the placement of fertilizer have shown that, when fertilizer is applied prior to planting, there is some advantage to be gained by banding the fertilizer into the seed bed to a depth of at least four inches. Broadcasting fertilizer and working it into the surface of the seedbed markedly increased yields, but was not as effective as the fertilizer placed in bands.

The average response from side-dressed applications of fertilizer was as great as that from any other method of application, but it presented several problems in actual practice. In several areas beets are irrigated up. Fertilizer in these districts should be applied before irrigation. This can only be done in sufficient amount and at sufficient depth if fertilizers are applied to the seedbed before planting. In other areas, where irrigations are delayed until after thinning, it has proven to be a bad practice to also hold the fertilizer application until after thinning. Generally, when side-dressing is delayed until after thinning, the soil is so dry and hard that side-dressing is difficult, irrigation is unduly delayed, and the job of side-dressing comes at a time when there is heavy press of other work, such as irrigation of grain, cutting of hay, and in some areas the planting of late crops such as late potatoes, beans, etc.

Application of fertilizer to the seedbed following fall or spring plowing makes it easy to apply the fertilizer sufficiently deep so that it is always in adequate soil moisture to make it available to the growing plant.

The main facts concerning the time and method of applying mixed fertilizer to the sugar beet crop may be summarized as follows:

1. The average yield increase from the application of from 400 to 600 pounds of mixed fertilizers such as 16-20-0, 15-11-0, 13-15-0 or 14-14-0, has been approximately 3 tons per acre.

2. It has made very little difference whether the fertilizer was applied during fall land preparation, during spring land preparation, between planting and thinning, or immediately following thinning. Time of application should be determined largely by convenience or other considerations involved.

3. Application of the entire amount of fertilizer in one heavy application has given greater yield response than has split applications in which the same amount of total fertilizer was applied at successive periods.

4. Broadcast applications of fertilizer worked into the soil surface were not quite as effective as band applications.

5. Fertilizer banded 4 inches deep into the seedbed prior to planting proved to be an effective method of application.

6. It appeared to make little or no difference whether bands of fertilizer were 10 inches apart or 20 inches apart.

7. There was no significant interaction between kind of fertilizer and method of application or time of application.

8. In view of the above facts, the most important consideration appeared to be the adoption of a program which would result in stimulating the use of a good mixed fertilizer to supply nitrogen and phosphorus in proper balance and in adequate amounts.

Literature Cited

TOLMAN, BION—Response to nitrogen and phosphate fertilizers in the Intermountain Area. Proceedings of American Society of Sugar Beet Technologists, pp 45-53, 1946.

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Fertilizer Placement for Sugar Beet Production[1]

JESSE L. MELLOR, HARVEY P. H. JOHNSON, AND ROBERT GARDNER[2]

The many questions regarding fertilizer efficiency as affected by placement have not received satisfactory answers. Perhaps they will never receive answers which will have wide spread application, but for specific soil, climatic, and cultural conditions there probably are positions of placement where the fertilizer materials approach maximum availability to growing plants. However, these positions may also vary with the stage of growth of the plants and with the type of fertilizer materials. Recent experiments conducted by Olsen and Gardner[3] with radioactive phosphate have shown that the most favorable placement for one type of phosphate may not be the best for another, and that the most favorable placement for a single type of material may vary during the season. The best position for a mixed fertilizer might not be the best for any of the single ingredients if applied separately.

A field experiment was started in 1947 in an attempt to determine the relative efficiencies of a few of the most commonly used methods of fertilizer placements for sugar beets. The experiment included commercial fertilizer alone and commercial fertilizer plus manure. The commercial fertilizer mixture consisted of ammonium nitrate, superphosphate (43% P_2O_5), and potassium sulfate at the rate of 65 pounds N, 86 pounds P_2O_5, and 50 pounds K_2O per acre. Manure was applied at the rate of 10 tons per acre. The experiment involved 14 separate treatments, described as follows:

1. Commercial fertilizer drilled with fertilizer attachment on grain drill before plowing.
2. Commercial fertilizer drilled 4 inches under seed at planting time.
3. Commercial fertilizer; 1/5 placed with the seed and 4/5 placed 4 inches deep and 5 inches to side of seed.
4. Commercial fertilizer 2 inches deep and 5 inches to side of seed.
5. Commercial fertilizer 4 inches deep and 5 inches to side of seed.
6. Commercial fertilizer; P and K 4 inches deep and 5 inches to side of seed with N side dressed before first irrigation.
7. Commercial fertilizer; P and K 4 inches deep and 5 inches to side of seed with N in first irrigation water.
8. Commercial fertilizer; all ingredients in first irrigation water. (P from phosphoric acid).

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[1] Conducted cooperatively by the Beet Sugar Development Foundation and the Colorado Experiment Station.

[2] Assistant Agronomist, Colorado Experiment Station; Agronomist and Statistician, Beet Sugar Development Foundation, and Agronomist, Colorado A & M Experiment Station, respectively. Authorized by the Director of the Colorado A & M Experiment Station for publication as Scientific Journal Series Article No. 326, received for publication February, 1950.

[3] Olsen, Sterling R., and Gardner, Robert. Utilization of Phosphorus from Various Fertilizer Materials. IV, Sugar Beets, Wheat, and Barley in Colorado. Soil Sci. 68: 168-169, 1949.

9. Commercial fertilizer; plow-sole application.

10. Commercial fertilizer 4 inches deep and 5 inches to side of seed with additional N in water at each irrigation.

10a. Commercial fertilizer mixed with the soil in a 4x4 inch band by a rototiller attachment and seed planted in the band.

11. Commercial fertilizer mixed with 10 tons manure per acre and broadcast before plowing.

12. Commercial fertilizer drilled in soil before application of ten tons manure and plowing.

13. Commercial fertilizer drilled in soil before plowing. Ten tons manure added as top dressing after plowing.

13a. Ten tons manure before plowing. Commercial fertilizer 4 inches deep and 5 inches to side of seed at planting time.

14. No commercial fertilizer or manure.

14a. No P or manure. N and K 4 inches deep and 5 inches to side of seed at planting time.

All the treatment numbers not followed by the letter "a" were in the first year's tests. The treatments 10, 13, and 14 were changed the second or third year to 10a, 13a, and 14a. The experiment was conducted the first and third years on the same tract of land with barley as the intervening crop between beet crops. Except for the changes indicated after the numbers followed by the letter "a," the treatments were placed on the same plots in the 1947 and 1949 experiments.

EXPERIMENTAL RESULTS

Stand of Beets

The data obtained in the course of the experiment include stand of beets, yield of beets, sugar percentage, yield of sugar, and results of plant tissue analysis. The data for simplicity and ease of comparison are presented as percentages of the data from untreated plots rather than as absolute values. Table 1 shows the relative number of beets at harvest as affected by the various treatments. It is evident from the table that the only important effect on stand resulted from the treament where part of the commercial fertilizer was drilled in the same furrow with the beet seed in 1948 (Treatment 3). This was an effect which did not occur in 1947 and probably would occur only under conditions of insufficient moisture at the time of germination. Commercial fertilizer placed with the seed reduced the stand to 54.7 per cent of the unfertilized check. In 1948 a dry period followed planting and placing the fertilizer with the seed probably intensified the drought effect which was not present in 1947. An apparent, but not significant, decrease in stand was caused by commercial fertilizer placed

directly under the seed (Treatment 2) and the rototiller treatment (Treatment 10a). In Treatment 2 the decrease probably was due to disturbance of the seed bed by the fertilizer shoes and resultant drought. In the case of the rototiller treatment, either disturbance of seed bed or drought aggravated by the fertilizer in the soil near the seed could have contributed to the reduced stand. There was an apparent but not significant average increase in stand on the fertilized plots over the non-fertilized plots in 1947 and 1948 which might have been due to the greater vigor of the fertilized plants.

Table 1.—Relative Stand of Beets

Placement	1947	1948	1949	Weighted Average***
1	112.1	104.3	99.8	105.1
2	99.3	97.7	96.0	97.7
3	108.4	54.7**	.....	.....
4	102.7	108.5	98.4	104.5
5	106.4	108.6	99.5	105.8
6	106.1	110.6	101.0	107.1
7	106.7	112.4*	103.4	108.7
8	105.7	101.6	99.1	102.0
9	107.7	105.0	99.8	104.4
10	108.8	.....	.....	.....
10a	.....	99.4	96.4	.....
11	113.1	106.0	96.7	105.5
12	112.5	101.1	100.0	103.7
13	105.1	.....	.....	.....
13a	.....	111.3	97.1	.....
14	100.0	100.0	100.0	100.0
14a	.....	.....	104.1	.....
Mean	106.7	101.5	99.4	104.0
LSD .05	N. S.	11.65	N. S.	N. S.
LSD .01		14.49		

* Significant .05 point
** Significant .01 point
*** Since 1947 and 1949 treatments were on the same plots, the averages of 1947 and 1949 yields were averaged with 1948 yields for "weighted average"

Yield of Beets

The average yield of beets per treatment for each of the three years was 13.76 tons per acre in 1947, 20.19 tons in 1948, and 20.51 tons in 1949. The lower yield in 1947 was probably due to late planting rather than a marked difference in fertility or moisture. In 1947 (Table 2) the average yield of the 14 treatment was 104.3 percent of the untreated check. In 1948 the average was 120.5 per cent of the check, and in 1949 it was 112.9 per cent.

In 1947 the manure and commercial fertilizer plowed under (Treatment 12) and P and K in a band at planting time with N side dressed just before irrigation (Treatment 6) yielded significantly more than the check. These treatments also yielded significantly more than commercial fertilizer plowed under (Treatment 1), plow-sole application (Treatment 9), all fertilizer in irrigation water (Treatment 8), and commercial fertilizer plowed

under with manure as a top dressing (Treatment 13). The average of the band placement at the time of planting was significantly better than commercial fertilizer drilled before plowing or the plow-sole application.

In 1948 the application of part of the fertilizer with the seed (Treatment 3) gave a yield not quite significantly lower than the unfertilized check, but significantly lower than any of the other fertilizer treatments. All of the fertilizer treatments except 3 gave yields significantly better than the non-fertilized check. The average of the manure treatments plus commercial fertilizer was significantly higher than the average yield of the commercial fertilizer treatments without manure. The yield for the treatment with the

Table 2.—Relative Yield of Beets

Placement	1947	1948	1949	Weighted Average***
1	92.7	122.4*	116.7*	113.6*
2	111.2	113.7*	112.4	112.8*
3	105.9	93.2	------	------
4	107.9	127.8**	110.0	118.4**
5	103.1	123.0**	106.9	113.9*
6	114.8*	122.9**	113.0*	118.9**
7	108.3	123.9**	105.0	115.3*
8	99.8	120.0**	116.0*	114.0*
9	93.6	121.6**	113.0*	112.5*
10	100.0	------	------	------
10a	------	117.5*	109.0	------
11	105.2	139.6**	132.4**	129.2**
12	112.3*	129.6**	121.0**	123.3**
13	93.0	------	------	------
13a	------	137.4**	127.5**	------
14	100.0	100.0	100.0	100.0
14a	------	------	107.9	------
Mean	104.3	120.5	112.9	115.6
LSD .05	12.42	13.25	12.49	11.11
LSD .01	16.59	17.66	17.18	15.81

* Significant .05 point
** Significant .01 point
*** See Table 1

fertilizer directly below the seed (Treatment 2) was significantly lower than the treatment with the fertilizer two inches deep and five inches to the side of the seed (Treatment 4).

In 1949 the three manure treatments, commercial fertilizer plowed under (Treatment 1), band placement of P and K with delayed side dressing of N (Treatment 6), the plow-sole application (Treatment 9) and commercial fertilizer all in the irrigation water (Treatment 8) yielded significantly higher than the check.

In comparing the average of the treatments which were carried through

all three years, the manure plus commercial fertilizer ranked highest and the treatment with delayed nitrogen application (Treatment 6) ranked highest of the treatments without manure. The two lowest in rank were the commercial fertilizer plowed under and the plow-sole application (Treatments 1 and 9).

Table 3.—Relative Yield of Sugar

Placement	1947	1948	1949	Weighted Average***
1	91.1	119.6**	110.5	110.2
2	109.6	113.0	108.5	111.0
3	102.5	88.0	.....	.....
4	103.3	128.0**	106.0	116.3
5	102.7	124.9**	100.0	114.2
6	112.4*	122.8**	108.3	116.6
7	106.7	122.3**	100.0	112.8
8	94.4	118.5**	111.6*	110.8
9	92.5	125.2**	112.7*	113.9
10	110.5	.....	.....	.....
10a	.....	117.6*	105.1	.....
11	103.0	130.9**	123.5	122.1
12	106.0	127.5**	113.8	118.7
13	91.3	.....	.....	.....
13a	.....	136.2**	119.9	.....
14	100.0	100.0	100.0	100.0
14a	.....	.....	106.7	.....
Mean	101.9	119.6	108.8	113.3
LSD .05	12.05	14.43	10.94	N. S.
LSD .01	16.12	19.24	14.51	

* Significant .05 point
** Significant .01 point
*** (See Table 1)

Yield of Sugar

The yield of sugar in general parallels the yield of beets (Tables 2 and 3) but the differences due to placement were much less pronounced in the sugar yield than in the beet yields. From the standpoint of sugar yield over the three-year period, there seems little choice between fertilizer placements. Most of the differences which were noted in individual years were less pronounced in the average. There evidently is a differential effect of placement and years, but the plan of the experiment would not permit calculation of the significance of this interaction.

There was no significant difference in sugar percentage during the three-year period but for individual plots there was a sufficient tendency toward an inverse relationship between sugar percentage and yield of beets to produce smaller differences in the yield of sugar than in the yield of beets.

A differential effect of stand of beets on the yield of beets and yield of sugar was noted in the case of the treatment with part of the fertilizer placed with the seed. Yield was only slightly reduced, but sugar percentage was also reduced, resulting in a greater effect on sugar yield.

Tissue Analyses

Differences in available nutrients in the soil frequently can be detected in analyses of plant tissues. Tissue analyses therefore are useful in comparing the efficiency of fertilizers and fertilizer placement. One advantage which tissue analyses have over yield response in such a comparison is that they show differences under high fertility conditions where there is no measurable yield response. Since this placement study was conducted on relatively high fertility land, they have been useful and might well have been conducted more extensively.

Table 4.—Relative Inorganic P in Petioles

Placement	1948	1949	Average
1	172.1**	119.5	145.8*
2	153.5**	126.2*	139.9*
3	165.1**	.....	.....
4	114.0	118.9	116.5
5	146.5**	118.2	132.4
6	132.6*	120.1	126.4
7	151.2**	121.7	136.5
8	107.0	89.6*	98.3
9	173.0**	110.9	142.0*
10a	100.0	157.8	118.9
11	204.7**	148.2**	176.5**
12	179.1**	161.6**	170.4**
13a	170.9**	143.3**	157.1**
14	100.0	100.0	100.0
14a	.....	80.5	.....
Mean	147.9	117.2	135.4
LSD .05	32.53	23.78	37.66
LSD .01	41.86	31.70	53.56

* Significant .05 point
** Significant .01 point

Tissue analyses were made only in the 1948 and 1949 seasons and for only one sampling each year. The 1948 samples were taken June 22, and the 1949 samples July 15. Differences in plant tissue phosphate between treatments (Table 4) were greater than differences in nitrate nitrogen (Table 5), probably because the N in the soil from sources other than fertilizers was relatively high at the time of sampling, and the amount from the fertilizers compared with the total available amount was relatively small. The most pronounced increase in phosphate in the plant tissues resulted from commercial fertilizer plus manure treatments. The large increase resulting from the combination compared to that from commercial fertilizer alone might have resulted from the high availability of the phosphate in the manure, the effect of manure on the availablity of applied phosphates, or the effect of manure on the availability of the natural soil phosphates. Of the commercial fertilizer treatments, the fertilizer drilled into the soil and plowed under and the plow-sole application were the highest in 1948, and the fertilizer directly under the seed was among the high treatments for both years.

For the average of the two years, the fertilizer plowed under ranked highest and the plow sole application second. The two treatments with the fertilizer plowed under gave the highest content of inorganic phosphates in the plant tissues, but were among the lowest yielding treatments. This may indicate that these were the best treatments so far as phosphate is concerned, but not the best for nitrogen, or that these treatments are best only in the early part of the season and that the phosphate in the band might be more available at a later period. More experimentation will be necessary to clarify these points.

Table 5.—Relative Nitrate N in Plants

Placement	1948	1949	Average
1	106.3	100.0	103.2
2	105.3	107.5	106.4
3	137.0*	.....	.....
4	114.8	98.7	106.8
5	115.3	94.3	104.8
6	98.4	89.9	94.2
7	84.1	88.1	86.1
8	127.5*	95.0	111.3
9	112.2	100.0	106.1
10a	94.7	105.0	99.9
11	121.2	102.5	111.8
12	112.7	105.0	108.9
13a	121.7	110.7	116.7
14	100.0	100.0	100.0
14a	.....	103.8	.....
Mean	110.80	100.04	104.3
LSD .05	25.92	N. S.	N. S.

* Significant .05 point

The only significant differences in the N during the two years occurred in 1948, and the only treatments differing significantly from any of the others were the treatment with part of the N fertilizer placed with the seed (Treatment 3) and the treatment with N applied in the irrigation water (Treatment 8). The larger increase in N from Treatment 3 can be explained from the poor stand and less competition for the N. There is no apparent reason why the N from Treatment 8 should have been higher than from Treatments 6 and 7 which were also delayed applications of N.

SUMMARY

The results of three years comparison of methods of fertilizer placement on relatively high fertility land have failed to show that on the average there is any outstanding difference between most of the fertilizer placement methods studied. The following differences were observed:

(1) There was an evident differential effect of season or location of experiments on the comparative results from the different treatments.

(2) The treatment where 100 pounds of the 500 pounds of commercial

fertilizer per acre used was placed in the same furrow with the sugar beet seed at the time of planting was found to be hazardous when moisture at the time of germination was critically low, and resulted in nearly a fifty per cent reduction in stand in 1948.

(3) The treatment where manure was spread on the surface after plowing gave poor results the one year that it was tried.

(4) For the fertilizer placements conducted through the three-year period, the commercial fertilizer drilled on the surface and plowed under and that put on the plow sole gave the lowest average yield of beets. The treatment with P and K placed in the band at the side of the seed at the time of planting and the N applied as a side dressing before the first irrigation gave the highest results of the treatments without manure. There was no significant difference at odds of 19:1 between placements 11, 12, and 13 when manure and commercial fertilizer were both applied and the manure was plowed under. However, commercial fertilizer applied in a band at the time of planting and commercial fertilizer placed on the manure before plowing gave better results than commercial fertilizer drilled into the soil before the application of the manure and plowing.

(5) The average of the treatments of both manure and commercial fertilizer gave significantly higher yields than commercial fertilizer alone, and the average of the treatments with commercial fertilizer alone gave significantly higher yields than the unfertilized plots.

(6) There was less difference in yield of sugar due to placement than in yields of beets.

(7) The phosphate in the plant tissues was highest early in the season for the treatments where the fertilizers were plowed under, indicating a higher availability of phosphate placed in that position for the early part of the season, if not the whole season. No significant differences in nitrate nitrogen in tissues were observed except for the treatment with low stand in 1948, which probably was due to less competition for N, and the treatment with all the fertilizer in the irrigation water. Both were significantly higher than the check.

Fertilizers Plowed Under Versus Soil Application at or After Planting[1]

RUSSELL T. NELSON[2]

Fertilization of sugar beets in northeastern Colorado has generally been accomplished by plowing under green and barnyard manures and drilling commercial fertilizers into the surface layers of the soil prior to planting, at planting, or after planting. The application of commercial phosphate fertilizezr on barnyard manure and plowing it under is not a new practice, but is nevertheless not used extensively. On occasions, water-soluble fertilizers such as phosphoric acid and nitrogen have been applied in irrigation water after the beets are beyond the thinning stage.

The experimental results reported in this paper were not set up primarily to study methods of application. Yet, the comparisons which it is possible to make between methods of application as a result of these tests serve well to further the information on this important subject.

Materials and Methods

The treatments used in the studies include both organic and inorganic fertilizers. There were four tests, all similar, conducted on farmers' fields in northeastern Colorado; namely, one each in the following factory districts: Windsor, Fort Lupton, Brush, and Sterling. The experimental design used was a randomized complete block with nine treatments and two replications per test. Restrictions were placed on the randomization of treatments since only one strip of sweet clover was planted per field. Consequently, the three treaments including sweet clover always made up the center six plots of the eighteen-plot test. The plots extended the length of the field but were no wider than to allow for ample borders on the sides of the two or four central rows used for yield measurements.

The four tests were started in the spring of 1947 by planting a strip of Hubam sweet clover through the central area of a spring-planted grain field (barley or oats) scheduled to be planted in beets in 1948. The strip was planted so that its course would be the same as that of the beet rows to be planted the following year. The sweet clover was allowed to grow for a time after the grain was harvested, but all fields were plowed before occurrnce of any severe frosts the fall of 1947.

A list of treatments used on tests initiated in 1947 and completed in 1948 is presented in Table 1.

The above fertilizers were applied with standard type farm equipment carefully calibrated and checked for the various rates of application. The harvest results were obtained in the same manners as in 1947 tests.[3]

One test of a different design conducted on the Experiment Station at

[1] Results presented are from projects conducted cooperatively by Colorado A & M College and The Great Western Sugar Company.

[2] Agronomist, The Great Western Sugar Company, Agricultural Experiment Station, Longmont, Colorado.

[3] Nelson, R. T., et al. Harvest results of inorganic fertilizer tests on sugar beets conducted in four states, 1947. Proc. Am. Soc. Sug. Beet Tech., pp. 407-420, 1948.

Table 1.—Kind, rate per acre, time and manner of application of fertilizers used as treatments in four tests, including sweet clover.

Tr. No.	Treatment
1	Sweet clover (Hubam).
2	Sweet clover + 250 pounds triple superphosphate broadcast on sweet clover and plowed under.
3	Sweet clover + 800 pounds finely ground raw rock phosphate broadcast on sweet clover and plowed under.
4	Barnyard manure 8 tons plowed under.
5	Barnyard manure 8 tons + 150 pounds triple superphosphate (broadcast on surface prior to manure application) and plowed under.
6	Inorganic fertilizer only; 250 pounds triple superphosphate + 200 pounds ammonium nitrate + 200 pounds muriate of potash broadcast and plowed under.
7	Same as 6 except fertilizers side-dressed immediately after planting beets.
8	Barnyard manure 20 tons, plowed under.
9	Check, without sweet clover or manure or inorganic fertilizer.

Longmont was placed on newly leveled ground on cut areas where depths of one to five feet of soil had been removed. The experimental design was that of a split plot with seven fertilizer treatments and two methods of application. Eight replications were made of each main treatment. Rates and kind of fertilizer formed the main plots, with method of application as top-dressing or side-dressing versus plowing under fertilizer being the subplots. Main plots were 22 feet wide and subplots 11 feet wide; all plots were 55 feet long. Kinds, amounts, and manner of application of fertilizers are listed in Table 2. The manure was analyzed and the treatment 10 tons manure + 100 pounds triple superphosphate was taken as a base rate. The elements applied by use of inorganic fertilizers in other treatments was calculated to coincide with this established base rate.

Table 2.—Fertilizer treatments in rate per acre applied to deeply cut, low fertility area, spring 1948.

Tr. No.	Treatment (a
1	Check, no fertilizer
2	Manure, 10 tons
3	Manure, 10 tons + triple superphosphate, 100 pounds (43 percent P_2O_5)
4	Ammonium sulfate, 567 pounds (20.5 percent N)
5	Triple superphosphate, 351 pounds
6	Treatment 4 + treatment 5
7	Treatment 6 + muriate of potash, 260 pounds (60 percent K_2O)

(a Each treatment was applied in two ways on different subplots:
A. Fertilizer broadcast before plowing and plowed under.
B. Fertilizers applied after plowing; treatments 2 and 3 were applied broadcast and disced in, whereas treatments 4-7 were side-dressed at planting time.

The yield results were obtained from the four center rows of each subplot. On the higher yielding plots only one-half the total number of beets were rasped for sugar analysis, while on the lower yielding plots all the beets were rasped and analyzed for sugar.

Results

In Table 3 are given the combined results for the four tests conducted in four different factory districts of northeastern Colorado.

Table 3.—Mean results of four tests. Tons beets, percentage sugar, and pounds sugar are given as increase or decrease over check.

Treatment No.	Treatment in rate per acre (a	Yield of Beets	Sugar Content	Total Sugar	Beets (b per 100′ of Row
		(tons/A)	(percent)	(lbs./A)	
9	Check, no clover or fertilizer	12.69	14.00	3580	82
1	Sweet clover (c	.25	—.52	—53	75
2	Sweet clover + 250 pounds 43% P_2O_5	.87	—.17	163	76
3	Sweet clover + 800 pounds rock phos.	.90	—.87	—16	82
4	Manure, 8 tons	1.16	—.12	261	72
5	Manure, 8 tons + 150 pounds 43% P_2O_5	1.94	—.14	481	78
6	250 pounds 43% P_2O_5 + 200 pounds NH_4NO_3 + 200 pounds Kcl	2.93	.04	601	84
7	Same as 6, but side-dressed	.92	—.11	180	77
8	Manure, 20 tons	1.68	—.23	338	81
LSD 5% pt.		1.36	ns	446	----
LSD 1% pt.		1.82	ns	ns	----

(a For more complete description of treatments see Table 1.
(b Average of only three tests.
(c Average yield 1.2 tons per acre air dry weight.

The results for the individual test conducted on subsoil exposed by leveling operations are presented in Tables 4 and 5.

Table 4.—Main plot treatments and harvest results for test conducted at Longmont

Tr. No.	Treatments in rate per acre(a	Tr. Totals N	P_2O_5	K_2O	Yield of Beets	Sugar Content	Total Sugar	Beets per 100′ of Row
		(lbs./A)			(tons/A)	(percent)	(lbs./A)	
1	Check	0	0	0	2.73	15.31	836	64
2	Manure, 10 tons	116	108	156	6.12	15.68	1919	84
3	Manure, 10 tons + 100 pounds 43% P_2O_5	116	151	156	6.47	15.35	1986	89
4	566 pounds ammonium sulfate	116	0	0	6.29	16.32	2053	68
5	351 pounds 43% P_2O_5	0	151	0	4.60	15.62	1437	85
6	Treatment 4 + treatment 5	116	151	0	9.86	15.34	3025	99
7	Treatment 6 + 260 pounds muriate of potash	116	151	156	8.41	16.88	2839	91
LSD 5% pt.					2.43	.85	777(b	20
LSD 1% pt.					3.27	1.14	1045	26

(a For more complete description of treatments see Table 2.
(b LSD calculated as for example:

$$\text{LSD} = \text{mean pounds sugar} \sqrt{\left[\frac{\text{LSD tons beets}^2}{\text{mean tons beets}}\right] + \left[\frac{\text{LSD \% sugar}^2}{\text{mean \% sugar}}\right]}$$

Discussion

The results in Table 3 show little gain in the yield of sugar beet roots from the growing and plowing under of Hubam sweetclover. In these tests the growth made by the sweetclover was somewhat disappointing. The amount of sweet clover plowed under on the different tests ranged from 0.7 to 1.5 tons per acre air dry weight. The individual analysis of variance on two tests showed no significant difference between treatments for yield at the 5% point, suggesting that these two fields were relatively high in fertility. The other two tests showed definite yield increases from manure and commercial fertilizers plowed under, while only one of these tests showed

a significant increase in yield for commercial fertilizer side-dressed. For the two tests, and as an average of the four tests, plowing under the commercial fertilizer, even though done in the fall, was more effective in increasing yields than a comparable application made as a side-dressing at planting time.

Results presented in Table 4 show the effectiveness of commercial fertilizers in sustaining plant growth in direct comparison with nutrient supplements supplied in the form of barnyard manure.

Table 5.—Harvest results for methods of application, as means of all treatments presented in table 4.

Treatments	Yield of Beets	Sugar Content	Total Sugar	Beets per 100′ of Row
	(tons/A)	(percent)	(lbs./A)	
A. Fertilizer broadcast and plowed under ahead of seedbed preparation	6.91	15.92	2200	88
B. Manure broadcast and disced in ahead of planting; inorganic fertilizers side-dressed immediately after planting	5.79	15.66	1813	77
LSD 5% pt.	.65	ns	209(a	5
LSD 1% pt.	.87	ns	282	6

(a Calculated by similar manner to footnote b, Table 4.

The results given in Table 5 indicate significantly higher yield for treatment A, fertilizer broadcast and plowed under, as compared with treatment B, including the discing in of manure and side-dressing of inorganic fertilizers at planting time. Results of other fertilizer trials in northeastern Colorado support the view that fertilizers should be placed relatively deep[4]. The statements on deep placement of fertilizer have usually been confined to refer only to phosphate. On the other hand, fertilizer applied during periods of limited precipitation, even if very water-soluble, may not penetrate below the applied depth. Irrigation water, if available, might be used to carry down the soluble fertilizer, provided the fertilizer is not pushed to the top of the ditch in the ditching operation to remain on high dry ground during most or all of the irrigation run. It was interesting to note that, on tests showing visible response to fertilizer, plots with the fertilizer applied and plowed under showed the response as early as the cotyledon stage of the beet plant. In the case of the test at Longmont, the greater vigor of the plants on subplots with fertilizer plowed under was undoubtedly responsible for the significantly better stand reported in Table 5. In regard to stand, the analysis of variance showed an interaction significant above the 1% level between method of application and fertilizer. In contrast to this, yield and sugar content did not show an interaction between method of application and fertilizer at the 5% level of significance.

Summary

Greater yields of beets and total sugar were secured where fertilizers were broadcast and plowed under as compared with similar fertilizers, and similar quantities, top- or side-dressed at planting time.

Inorganic fertilizers containing N and P or NP and K gave equal or greater production of beets and total sugar than did comparable amounts of NP and K applied in similar manner in the form of barnyard manure.

[4] Whitney, Robert S., Robert Gardner, and D. W. Robertson. Methods of increasing the productive capacity of subsoils exposed by leveling. I. Manure and commercial fertilizer. Jour. Am. Soc. Agron. (in press), 1950.

Sugar Beet Fertilization in Wisconsin

K. C. BERGER[2]

Although sugar beets have a relatively high requirement for nitrogen, potassium, and boron, in general only a small amount of fertilizer has been used on sugar beets in the past in Wisconsin. As a result, yields of sugar beets are low, with the state yield average around 9 to 10 tons per acre. Because of this, soil fertility investigations with sugar beets as reported in this paper were initiated in 1940. Experiments were conducted in the field in most of the years since that time.

During the course of the investigations, nutrient disorders of sugar beets, involving potassium deficiency, boron deficiency, nitrogen deficiency, nutrient unbalance and the effect of acid soils have appeared in the soil. The low yields in the state can, to quite an extent, be attributed to the above unbalanced fertility conditions. A number of experiments were conducted during this period to study the effect of soil reaction, nutrient balance, high potash fertilizers, effect of boron fertilization and the effect of salt. The results of these investigations are reported here.

A part of the investigations reported here have been previously reported in annual progress reports (1) (2) (3) (4).[3]

Procedures

In all field experiments, 4 replications of each treatment were made in a randomized block arrangement. Individual plots were 4 rows wide and 60 feet long. The fertilizer applied in the row was applied in 2 bands about 1½ inches to the side of the seed and slightly below with a shoe-type fertilizer beet drill. Fertilizers applied broadcast were weighed out for each plot and applied by hand after plowing and then were disced thoroughly into the soil. The broadcast application of fertilizer was double disced so as to mix it with the top 3 to 5 inches of soil.

For harvest, 5 feet were removed from each end of the plot and the center 2 rows 50 feet long were taken for yield. The beets were hand-topped and weighed in the field and the yields were calculated to an acre basis. The amount of sugar was determined in each case.

Available phosphorus and potassium determinations and the pH of the soil were determined by the Truog quick test procedure. Available boron was determined by the Berger-Truog quinalizarin method. Soil samples were taken from each plot before fertilizers were applied and 3 to 5 cores to the depth of the plow layers were taken for each sample.

Effect of Soil Acidity on Yield

Preliminary observations have indicated that the pH of the soil affected the yield of sugar beets considerably. It was observed that yields were quite commonly higher on neutral or alkaline soils than they were on soils of strong to medium acidity, even though beets were fertilized alike. Results

[1] Contribution from the Department of Soils, University of Wisconsin, Madison 6, Wis. Published with the permission of the Director of the Wisconsin Agricultural Experiment Station.

[2] Professor of Soils.

[3] Figures in parentheses refer to "Literature Cited."

given in Table 1 show the influence of soil reaction on yield of beets at three different fertility levels. These results were obtained in eight different experiments, conducted in different years with 4 of the experiments located on soils more acid than pH 5.9 and the other 4 on soils which were neutral or alkaline. In each field the treatments were replicated 4 times and were randomized and the average yields are given in Table 1. When no fertilizer was applied the beets on the acid soils yielded about 11 tons to the acre, while those on the neutral or alkaline soils yielded about 15 to the acre.

Table 1.—Yield of sugar beets on neutral and medium acid soils with various fertility levels.

	Acre yield in tons[1]		
Soil Reaction	No fertilizer	Fertilizer at[2] side of seed Borax broadcast	Fertilizer at[3] side of seed Borax plus high potash fertilizer broadcast
Lower than pH 5.9	11.1	14.2	18.5
Higher than pH 7.0	15.1	18.1	23.0

[1] Average of 4 fields at each pH level with 4 randomized replications in each test.
[2] Fertilizer application 150 to 200 pounds of 3-12-12 at side of seed plus 25 lbs. borax broadcast.
[3] Fertilizer application 800 to 1,500 lbs. of 6-6-18 or its approximate equivalent and 25 lbs. borax broadcast. Row application of 150 to 200 lbs.; 3-12-12 in addition. Broadcast fertilizer composition changed from year to year but in each case the fertilizer was the same on the acid and neutral soil.

When a small amount of starter fertilizer was applied at the side of the seed, together with Borax, these yields were increased about 3 tons to the acre, but the difference between limed and unlimed soils remained constant. When heavy applications of high potash fertilizer were applied broadcast, in addition to the row fertilizer, the yield was increased about 4 tons in the case of the acid soils, and about 5 tons in the case of the neutral soils.

In one experiment on a strongly acid soil, 2,000 pounds of finely powdered dolomitic limestone were applied broadcast at seeding time and in this experiment the yield was increased 3 tons per acre by the application of lime. This comparison was made with the high fertility level and yields increased even though the lime probably did not dissolve completely in the soil.

These soils varied from 10 to 50 pounds of available phosphorous per acre and from 110 to 200 pounds of available potassium per acre. The acid soils ranged in pH from 5.3 to 5.9 while the neutral or alkaline soils varied from pH 7.0 to 8.0.

The figures given in Table 1 show the great importance of liming under Wisconsin conditions.

Influence of Soil Fertility on Yield

Early in the experimental work it was found that under Wisconsin conditions maximum yields could not be obtained with the application of 150 to 200 pounds of fertilizer at the side of the seed in the row. Because beets are heavy users of nitrogen and of potash while using only relatively small amounts of phosphorus, experiments were initiated in which heavy applications of high potash fertilizers were applied broadcast. These experiments

were conducted on Superior clay loam, Carrington silt loam, and Miami silt loam, the three most important soil types for sugar beets in Wisconsin. The Superior clay loam is a red soil of lacustrine origin, usually neutral or slightly alkaline in reaction, containing from 150 to 250 pounds per acre of available potassium and 40 to 50 pounds of available phosphorus per acre.

The Carrington silt loam is usually high in organic matter and is a Prairie soil derived from calcareous glacial drift. This soil is usually acid, ranging in pH from 5.2 to 5.7, containing 10 to 50 pounds of available phosphorus per acre and 110 to 150 pounds of available potassium.

Table 2.—Yield of sugar beets as influenced by three levels of fertility on various soil types.

Soil Type	Acre yield in tons[1] No fertilizer	150 to 200[2] pounds 3-12-12 side-seed	Broadcast[2] plus 150 to 200 3-12-12 side-seed	Broadcast fertilizer Pounds	Grade
Superior clay loam	16.5	21.0	24.0	1000	0-10-25
Carrington silt loam	8.2	11.8	17.7	1000	0-10-25
Superior clay loam	16.5	20.7	26.8	1000	0-10-30
Carrington silt loam	15.2	18.0	21.1	1000	0-10-30
Carrington silt loam	9.9	14.2	18.1	1600	5-7.5-22.5
Miami silt loam	10.9	13.0	17.2	1600	6-6-20
Miami silt loam	7.5	10.3	14.7	1200	6-6-20
Miami silt loam	9.3	12.5	17.6	1200	6-6-18
Average	11.8	15.2	19.2		

[1] Average of 4 randomized replications.
[2] Borax applied at the rate of 25 pounds per acre broadcast.

The Miami silt loam is derived from calcareous glacial till, and was developed under deciduous forest. This soil has a pH of between 5.7 and 7.2, containing 40 to 50 pounds of available phosphorus and 125 to 170 of available potassium.

The data given in Table 2 show that in every case, on these soils, yields were increased over the untreated plots by the application of 3-12-12 at the side of the seed. For all the experiments this amounted to an average of 3½ tons of beets per acre. When additional high potash fertilizer was applied broadcast, the yields were increased over the row application alone in every case also, the average increase being 4 tons per acre, with the largest increase being about 6 tons on one experiment. In this experiment the broadcast plus the row application of fertilizer resulted in a yield of 26.8 tons of beets per acre. In the first experiments, phosphate and potash were broadcast but later nitrogen deficiencies have appeared and better results have been obtained with some nitrogen in the fertilizer. In recent years, the fertilizer giving the best results for broadcast application with sugar beets has been the 6-6-18 mixture applied at the rate of 800 to 1,200 pounds per acre.

Influence of Boron on Sugar Beet Yield

Boron deficiencies in sugar beets were found in scattered areas soon after the work was started and, in all experiments since that time, boron has been included in the tests. When soil tests have been correlated with yields,

it was found that usually sugar beets did not respond to boron fertilization when the soils contained 2 pounds per acre or more of available boron. When the soils were lower than this increases in yields were obtained consistently with boron fertilization, even though in none of the experiments reported here boron deficiency symptoms were present.

Figures given in Table 3 show that on low boron soils the application of 25 pounds per acre broadcast or 15 pounds per acre of Borax at the side of the seed increased the yield, on the average, 2 tons per acre. The data also show that, when there is sufficient boron in the soil, yield increases were not obtained.

Table 3.—Yield of sugar beets grown of various soil types with and without boron fertilization.

Soil Type	Available boron in soil Lbs. per acre	Acre yield in tons[1]		
		Without boron fertilization	Borax applied broadcast 25 lbs. per acre	Borax applied side seed 15 lbs. per acre
Superior clay loam	1.4	18.7	20.7	19.5
Miami silt loam	1.1	8.5	10.3	11.8
Superior clay loam	1.7	18.9	21.0	20.4
Average of low boron soils	1.4	15.4	17.3	17.2
Carrington silt loam	2.0	18.8	18.0	17.8
Miami silt loam	2.0	13.3	13.0	12.6
Carrington silt loam	2.6	11.8	11.8	
Carrington silt loam	2.2	13.1	14.2	12.8
Average of high boron soils	2.2	14.3	14.3	14.4

[1] Average of 4 randomized replications.
All plots received 200 lbs. of 3-12-12 per acre at the side of the seed.

When the Borax is applied at the side of the seed in the row and the rate, on silt or clay loam soils, increased to 40 pounds per acre, annual weeds in the row can often be controlled without injury to the sugar beets to such an extent that hand weeding is unnecessary. Deep-rooted perennial weeds, such as Canada Thistle and quack grass, will not be affected by this treatment, however. Considerable work with canning beets has been done on this method of weed control, and preliminary investigations with sugar beets have also indicated that it is successful. The Borax must be applied at both sides of the seed so that it is not in direct contact with the seed or the stand of beets will be reduced.

Use of Sodium

Several experiments were conducted in which part of the potassium in the fertilizer was replaced with an equivalent amount of sodium, and results, although not conclusive, indicate that sodium may to a certain extent replace part of the potassium needed by the sugar beets, and that in addition sodium might also have some stimulating effect on the beets. Results at present, however, are not conclusive enough to warrant presenting data.

Summary

Results presented show that soil reaction is a very important factor on sugar beet yields in Wisconsin. Yields in experimental plots averaged 4 to

4½ tons higher on neutral or alkaline soils than on soils with medium acidity at three fertility levels.

Results presented show that for maximum yields of sugar beets it is necessary to apply a high potash fertilizer broadcast in addition to the row fertilizer application. This treatment resulted in an increase in yield over row fertilization of 4 tons per acre and an increase of 8½ tons per acre over the unfertilized plots. The figures presented are an average of 8 different experiments conducted on different soils in different years. At the present time, a 6-6-18 fertilizer appears to give the best results when applied broadcast.

When soils contain less than 2 pounds per acre of available boron, the application of Borax, either broadcast or at the side of the seed in the row, resulted in an increase in yield of about 2 tons of beets per acre when the beets were fertilized with row fertilizer in addition to the Borax.

None of the treatments presented influenced significantly the percentage of sugar in the beets or the purity.

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Summary of Fertilizer Results—1949

ANDREW R. DOWNIE[1]

The territories served by the American Crystal Sugar Company are widely scattered. For this reason the fertilizer requirements are not the same for all places. Fertilizer tests, therefore, have to be planned for the particular area. The tests as conducted in 1949 will be taken up by areas.

Tests in the California Area

As has been previously pointed out (1)[2], the general fertilizer practice in this area is to apply liberal applications of nitrogenous fertilizers either at the time of seed bed preparation or as a side dressing shortly after thinning. These practices generally result in increased tonnage and in some cases a decreased sugar content.

Two tests are reported from this area, one conducted in the San Joaquin valley and the other near Clarksburg, California. Table 1 gives the fertilizer, pounds of plant food per acre and the yields obtained in the test conducted in the San Joaquin valley at Visalia. This test was planted as a 10x10 Latin square but since only six complete blocks could be harvested it is analyzed as a randomized block.

Although all treatments except the heavy rate of the 16-20-0 show higher tonnages than the check, only the three rates of ammonium sulfate and the two higher rates of 10-10-5 appear to be profitable.

Table 1. Results of San Joaquin Fertilizer Plot Test—1949

Fertilizer	Lbs. Plant Food per Acre	Tons Beets per Acre	% Sucrose	Lbs. Sugar per Acre
21-0-0	45	35.66	13.63	9,721
21-0-0	60	34.49	13.28	9,162
21-0-0	30	33.51	13.34	8,941
10-10-5	45	32.09	13.28	8,524
10-10-5	60	32.27	13.04	8,415
16-20-0	45	31.95	12.73	8,140
10-10-5	30	31.15	12.91	8,042
16-20-0	30	30.84	12.85	7,927
Check	....	29.84	13.18	7,865
16-20-0	60	30.27	12.54	7,591
General Mean		32.21	13.08	8,424
Sign. Diff. (19:1)		4.84	1.03	1,505

The other test reported in this area was carried out near Clarksburg on a semi-peat soil. All of the fertilizers were applied at the rate of 75 pounds of plant food per acre. The results are given in Table 2.

Only the 16-20-0 and the 0-43-0 fertilizers gave a significant increase in yields over the unfertilized treatment.

Arkansas Valley, Colorado, Area

The tests in this area were in the form of strip tests in farmers' fields. Five fertilizer combinations were applied on twelve row strips running the entire length of the field with two such strips for each fertilizer treatment

[1] Plant Pathologist, American Crystal Sugar Company, Rocky Ford, Colorado.
[2] Numbers in parentheses refer to literature cited.

Table 2. Results of Clarksburg Fertilizer Plot Test—1949

Fertilizer	Tons Beets per Acre	% Sucrose	Lbs. Sugar per Acre
16-20-0	27.95	15.34	8,574
0-43-0	26.74	15.23	8,146
21-0-0	24.72	15.48	7,652
10-10-5	24.41	14.92	7,283
0-0-0	23.68	15.29	7,244
6-12-6	24.83	14.58	7,240
General Mean	25.39	15.14	7,690
Sign. Diff. (19:1)	2.88	1.13	1,020

at each location. The data for the four locations were combined and the analysis is presented in Table 3.

Table 3. Arkansas Valley Fertilizer Strip Tests—1949
Average of Four Locations

Fertilizer	Rate per Acre	Tons Beets per Acre	% Sucrose	Lbs. Sugar per Acre
0-43-0	250	15.92	15.22	4,823
16-20-0	300	15.99	14.86	4,694
0-43-0 and 20-0-0	175-150	15.20	15.11	4,573
4-24-4	335	14.71	15.58	4,545
6-30-0	300	14.78	15.35	4,470
0-0-0	.....	14.16	15.36	4,326
General Mean		15.12	15.25	4,572
Sign. Diff. (19:1)		1.57	.49	501

The results obtained fall in line fairly well with fertilizer results obtained over the past five years. It may be noted that the highest phosphate fertilizer resulted in the highest yield and that the highest application of nitrogen fertilizer tended to reduce sucrose percent in the beets.

Northern Iowa-Southern Minnesota Area

The tests in these two areas were conducted in the same manner as those for the Arkansas valley except that there were no unfertilized treatments. The beneficial response to fertilizers is so general in these areas that the farmers object to having unfertilized strips in their fields.

The results for the strip tests in Northern Iowa are presented in Table 4 and for Southern Minnesota in Table 5.

Table 4. Northern Iowa Fertilizer Strip Tests—1949
Average of Five Locations

Fertilizer	Rate per Acre	Tons Beets per Acre	% Sucrose	Lbs. Sugar per Acre
4-24-4	187	14.48	17.26	4,981
3-18-9	251	13.57	17.46	4,723
0-43-0	188	13.87	17.04	4,706
13-28-0	191	13.53	17.09	4,613
33-0-0	144	13.07	16.40	4,258
General Mean		13.70	17.05	4,656
Sign. Diff. (19:1)		1.25	.50	390

Table 5. Southern Minnesota Fertilizer Strip Tests—1949
Average of Three Locations

Fertilizer	Rate per Acre	Tons Beets per Acre	% Sucrose	Lbs. Sugar per Acre
4-24-4	235	13.52	15.98	4.295
20-0-0	200	12.43	16.25	4.029
0-43-0 and 20-0-0	100-100	12.31	16.24	3.987
3-18-9	250	12.53	15.83	3.977
0-43-0	175	12.21	15.95	3.879
General Mean		12.60	16.05	4.034
Sign. Diff. (19:1)		.58	.37	165

In both areas the outstanding fertilizer was 4-24-4. Similar results have been obtained for the last four years of testing.

Red River Valley, Minnesota

High phosphate fertilizers have given the best performance in this area Almost universally the beet crop is preceded by summer fallow which in turn was preceded by a green manure crop. The nitrogen content of the soil seems to be quite adequate since small increments of this nutrient tend to depress sugars somewhat. The results for this area are presented in Table 6.

The results of this year's testing indicate that 0-36-8 and 0-43-0 give the greatest yield increment.

Table 6. Red River Valley Fertilizer Strip Tests—1949
Average of Six Locations

Fertilizer	Rate per Acre	Tons Beets per Acre	% Sucrose	Lbs. Sugar per Acre
0-36-8	150	13.17	17.72	4.666
0-43-0	150	13.07	17.38	4.541
2-32-8	150	12.95	17.31	4.461
4-24-4	200	11.58	17.37	4.025
General Mean		12.70	17.45	4.423
Sign. Diff. (19:1)		.80	.52	303

Summary

The fertilizer test in the San Joaquin valley emphasizes the need for high nitrogen fertilizers while the test on semi-peat soil at Clarksburg, California, showed that phosphate was needed in the fertilizer mixture.

High phosphate fertilizer is required for maximum yields in the Arkansas valley, Colorado.

The complete fertilizer 4-24-4 gave the highest yield increment in Northern Iowa-Southern Minnesota area.

The highest yields were obtained in the Red River valley, Minnesota, with high phosphate fertilizers. Even small increments of nitrogen tend to lower sucrose and yield.

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The Production of Sugar Beets on a Saline Soil as Affected by the Type of Leaching[1,2]

WITH SPECIAL REFERENCE TO THE VALUE OF PRE-EMERGENCE IRRIGATION

WALTER R. HEALD, C. D. MOODIE, AND ROSS W. LEAMER[3]

INTRODUCTION

Saline soils are numerous in the lower Yakima valley in south central Washington. The areas in which salts have accumulated in quantities detrimental to plant growth vary in size from spots of several square yards to whole fields. The sugar beet, because of its high salt tolerance, once it is established, is the principal crop grown in these saline soils.

The failure to obtain profitable yields of sugar beets on saline soils is due to failure to obtain satisfactory stands, and to reduction in growth of the beets once a stand is established. This report is concerned with the effects upon the stand and yield of beets of leaching a saline soil during the winter to lower the salt concentration in the root zone, and of irrigation in rills adjacent to the beet row during the period of germination to lower the salt concentration in the viginity of the germinating beet seed. Since the rill irrigations adjacent to the beet row were applied during the germination period and before the beets emerged, this type of irrigation is referred to as pre-emergence irrigation.

PROCEDURE

Plots were established on Esquatzel loam in a 6-acre field near the town of Sunnyside, Washington. Although the soil in this particular field is saline-alkali it contains 1 to 2 per cent of gypsum; and in behavior it is representative of many of the saline soils under crop in this region. Typically, the salt content of the soil is variable from place to place and with depth, but ranges from 2,000 to 10,000 p.p.m. ($EC \times 10^3 = 3$ to 15[3]).

Water was applied during the winter in two general ways: by furrow irrigation at two rates, and by flooding at 4 rates. Pre-emergence irrigation

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[1] Published as Scientific Paper No. 892, Washington Agricultural Experiment Stations, Institute of Agricultural Sciences, State College of Washington, Pullman. From a thesis submitted by Walter R. Heald to the faculty of the State College of Washington in partial fulfillment of the degree of Master of Science in Agriculture.

[2] This report is concerned with a portion of the work carried out under a Memorandum of Agreement among the Utah-Idaho Sugar Company, the Washington Agricultural Experiment Stations, and the Bureau of Plant Industry, Soils, and Agricultural Engineering.

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was applied appropriately for 8-hour periods at weekly intervals; 0, 1, or 3 irrigations to the plots in the furrow irrigation series, and 0 or 3 irrigations to plots in the flooded series. Each plot within the furrow irrigation series was split for seed rate; 3 or 7 pounds of segmented seed.

Following winter leaching, the field was leveled and a uniform placement of 80 pounds of N and 110 pounds of P_2O^5 per acre was made over the entire field in bands 3 inches deep and 11 inches apart at right angles to the furrows.

All plots were planted with segmented seed of the variety of U. S. 22 on March 30 and 31, 1948. The furrows for pre-emergence irrigation were opened within 2 to 3 inches of the beet row by means of special disks attached to the frame of the 6-row drill used for planting. When the beets were thinned, new furrows for normal irrigation were made in the center between the rows.

Following the winter leaching treatments and pre-emergence irrigation, all field operations were those used by farmers. The beets were pulled, topped, counted, and weighed on November 16 and 17, 1948. Only beets more than 2 inches in diameter were counted and weighed.

A measure of the concentration of salts in each plot following winter leaching was obtained by determining the electrical conductivity of 1:1 soil: water extracts. These data are not presented here.

All the data have been averaged. Although the rate of seeding had some small influence upon the stand of beets after thinning, it had no significant effect upon the number of marketable beets[4]. The number of beets per 100 feet of row, and the yield of beets in tons per acre, are reported in Tables 1 and 2.

RESULTS AND DISCUSSION

The Effect of Pre-emergence Irrigation on the Stand and Yield of Beets

Pre-emergence irrigation has the effect of moving salts laterally out of the beet row, thereby improving germination and emergence. The stand is improved whenever pre-emergence irrigation is applied, but the greatest improvement is apparent in plots from which no salt was removed by winter leaching. Up to a certain point, the yield of beets is a function of the density of stand. Three pre-emergence irrigations applied to plots receiving no winter leaching increased the stand of beets from 20-30 beets per 100 feet of row to 80 beets per 100 feet of row, and increased the yield from 4 to 11 tons in one experiment (Table 1) and from 8 to 20 tons in another (Table 2). However, stand density is not the sole reason for increased yield. Above a certain stand density (approximately 70 to 80 beets per 100 feet of row in this study), the yield is determined principally by factors other than stand since significant increases in the numbers of beets resulting from pre-emergence irrigation are not accompanied by significant increases in yield.

Placement of furrows for pre-emergnce irrigation is fundamentally different from that of furrows for normal irrigation. The normal consequence of water moving from a furrow into saline soil is the movement of salts

[4] The measurement of salt concentration in this study was in terms of electrical conductivity of the 1:1 soil: water extract expressed as millimhos per cm. (E C x10^3). The approximate expression in p.p.m. is obtained by multiplying the electrical conductivity x 700. The relationship of the conductivity of the 1:1 extract (EC 1:1) to that of the saturation extract (EC_e) is expressed in the equation $EC_e = -2.5 + 2\ EC_{1:1}$.

laterally and vertically away from the furrow. In the case of pre-emergence irrigation, the salts are moved laterally *past* the beet seed which can then germinate and emerge from a soil zone relatively low in salts. In contrast, normal irrigation moves salts effectively *into* the beet row. Thus, it is apparent that the placement of the furrow for pre-emergence irrigation must be as close as possible to the seed, if it is to be effective. Irrigation in the usual manner would have the opposite effect.

Table 1. The Number and Yield of Marketable Sugar Beets as Affected by Winter Leaching (Furrow Irrigation) and Pre-emergence Irrigation.

Winter treatment	Number of pre-emergence irrigations 0	1	3
	Average Number of Beets in 100 ft. of row*		
None	26.9 ± 5.9+	68.9 ± 3.7	81.8 ± 2.5
Leached by furrow irrigation**	74.1 ± 5.6	82.3 ± 4.1	91.3 ± 3.9
	Average Yield of Beets in T/A***		
None	7.9 ± 2.0	17.4 ± 1.2	20.4 ± 1.1
Leached by furrow irrigation**	20.5 ± 2.2	22.2 ± 1.2	24.4 ± 1.6

*Based upon the number of marketable beets in 160 feet of row; averages for 12 plots.
**A total of 6 to 8 acre inches was applied.
***Based on the net weight of beets in 160 feet of row; averages for 12 plots.
+The value following the ± is the standard deviation of the average yield.

Inasmuch as little extra effort is involved in applying pre-emergence irrigation, the increases in yield shown, 12 tons in one case (Table 1) and 7 tons in another (Table 2), represent a substantial and significant gain to the beet grower.

The Effect of Winter Leaching on the Stand and Yield of Sugar Beets

The data presented in Tables 1 and 2 show the value of winter leaching, and consequently of salt removal, in improving the productivity of saline soils. Data obtained (1), but not presented here, show that, in general, the stand and yield of beets is proportional to the concentration of salts in the region of the growing plants. A stand can be established by reducing temporarily the salt concentration for the young beet plant by means of pre-emergence irrigation. However, with the beginning of normal irrigation (which follows thinning) this more favorable environment for the beet is lost, and for the greater part of its life the beet must grow in highly saline soil. Thus, after a stand of beets has been established by a saline soil by pre-emergence irrigation, the yield of beets is still affected and finally determined principally by the salt concentration.

Winter leaching with 6 to 8 inches of water by furrow irrigation reduced the salt content in the first foot of soil, but did not materially change it below that depth (1). The effect of this relatively minor removal of salt was to increase the yield of beets by approximately 12 tons on plots receiving no other treatment, and by 4 to 5 tons when a stand was established by pre-emergence irrigation (Table 1).

Winter leaching by flooding was highly effective in removing excess salt from the soil. The extent of removal was proportional to the amount of water used. Twenty-four inches of water reduced the salt content by 50

per cent throughout the first 3 feet of soil (1). The extensive salt removal by flooding increased the stand of beets by 400 to 500 per cent. It increased the yield by 21 tons per acre for 12 inches of water, and by 28 tons for 24 inches of water on plots receiving no other treatment.

It may be concluded, then, that pre-emergence irrigation is effective in establishing a stand of beets on saline soils. This practice should be highly profitable to the beet grower, since the establishment of a stand guarantees a yield of beets not otherwise obtainable. The ultimate goal,

Table 2. The Number and Yield of Marketable Sugar Beets as Affected by Winter Leaching (Flooding) and Pre-emergence Irrigation.

Winter treatment	Number of pre-emergence irrigations	
	0	3
	Average Number of Beets in 100 feet of row*	
None	22.0 ± 5.8+	83.0 ± 2.7
Flooded (12 inches)	87.3 ± 2.7	99.3 ± 3.5
Flooded (17 inches)	94.3 ± 3.2	104.3 ± 5.5
Flooded (24 inches)	98.3 ± 4.0	105.5 ± 2.5
	Average Yield of Beets in T/A**	
None	4.1 ± 1.2	11.0 ± 1.1
Flooded (12 inches)	24.7 ± 1.7	26.7 ± 0.9
Flooded (17 inches)	29.7 ± 1.5	27.7 ± 2.6++
Flooded (24 inches)	32.4 ± 1.1	29.5 ± 1.7

*Based upon the number of beets in 180 feet of row. Averages for 4 plots.
**Based upon the weight of beets in 80 feet of row. Averages for 4 plots.
+The value following the ± is the standard deviation of the average yield.
++This value includes only 3 plots.

however, must be to remove permanently the major part of the excess salts, since it is only thus that good yields of all crops can be obtaind.

CONCLUSIONS

The principal conclusions to be drawn from this study of the effect of the type of leaching upon the production of sugar beets on a saline soil can be summarized as follows:

1. *Failure to produce profitable yields of sugar beets on saline soils is due principally to two factors: failure to obtain a full stand of beets, and reduced growth of the beets once a stand is established.*

2. *The application of irrigation water in standard furrows causes salts to move laterally and vertically away from the furrow and to accumulate in and on the ridges and around the sugar beets.*

3. *Removal of harmful salt can be accomplished by leaching, provided drainage can be established.* Leaching to remove salts is carried out most effectively by flooding but can be carried out slowly by applying water in furrows during the non-growing season or by *over-irrigation* during the growing season.

4. *The removal of salts is beneficial for both germination and emergence of the beets and for their subsequent growth.* The benefit is most pronounced in the improvement in stand, because the period of germination and emergence of the sugar beet is the most critical in its development in saline soil. Once the young beet is established, it is appreciably salt-tolerant.

5. *Irrigating after planting in special furrows placed close to the beet row brings about a temporary reduction in salt concenération in the vicinity of the germinating beet seed, thereby substantially improving the germination and emergence.* This practice, termed pre-emergence irrigation, makes it possible to establish fair to good stands even in highly saline soil when little or no stands can be established by the usual practices. At thinning time, these special furrows are abandoned and new furrows are made between the rows.

6. *Stands were increased from 20 or 30 beets to 70 beets per 100 feet of row with 1 pre-emergence irrigation, and to 80 beets per 100 feet of row with 3 pre-emergence irrigations in plots from which no salt had been removed by winter leaching. This increase in stand resulted in increases in yield from 8 to 20 tons in one series of plots and from 4 to 11 tons in another.*

7. *Above a certain stand density (approximately 70 to 80 beets per 100 feet of row), the yield is determined by factors other than stand, principally salt concentration; because, once a stand is established, the yield increase is roughly proportional to the decrease in salt.*

8. *For maximum yields, it is necessary to remove salts by leaching. Thus where pre-emergence irrigation increased yields from 4 to 11 tons per acre on plots not winter leached, flooding with 12, 17, and 24 inches of water increased the yields of beets from 4 to 25, 30, and 32 tons per acre respectively.*

9. *Pre-emergence irrigation probably should not be applied to soils which crust over seriously by drying. Crusting may effectively prevent emergence of the beet seedlings.*

10. *Pre-emergence irrigation is a valuable practice which should enable the grower to establish a stand of beets on a saline soil and thus obtain some yield on otherwise waste land. If at the same time sufficient water is applied to remove salt from the field, a permanent and profitable reclamation is possible. It should be emphasized that it is necessary to establish drainage before a permanent reclamation can be effected.*

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Use of IPC for Weed Control in Sugar Beets[1]

G. W. DEMING[2]

In recent years limited trials of some chemical weed killers have been made in connection with sugar beet experiments at Fort Collins, Colorado.[3] In 1947, following suggestions by J. W. Mitchell and P. C. Marth[4], observations were made on the effect of Isopropyl-N-Phenyl-Carbamate (IPC) applied dry and worked lightly into the surface of the soil at the rate of 40 pounds per acre. Weed control was excellent and adequate stands of sugar beets were obtained from moderately heavy plantings of beet seed. However, observations suggested the possibility of slightly adverse effect of the chemical on early growth of the sugar beet seedlings.[5]

A more comprehensive test was planned for 1948, with IPC applied at rates of 10, 20 and 30 pounds per acre on replicated plots. Rainfall in April and May was below normal, resulting in variable and usually inadequate soil moisture for normal germination of beet seed. The stands of beets were poor and the experiment was not carried to harvest. Observations indicated a marked reduction of weeds on the treated plots. That a slight reduction in emergence of beet seedlings had been caused also appeared probable. No consistent differences attributable to different rates of application of IPC were apparent.

TABLE 1.—Seedling counts; IPC treated and check plots at Fort Collins, Colo., 1949. Data given as 2-plot averages. (20 counts per plot of 4"x12" quadrats, lengthwise of beet row.) Planting date April 25. Surface application of IPC, 10 pounds per acre.

Treatment	Date of count	Seeding rate 4.3 lb.			Seeding rate 2.3 lb.		
		Beets	Grasses	Dicots.	Beets	Grasses	Dicots.
Check	May 18	6.98	9.48	1.00	3.58	13.09	0.92
IPC	May 18	4.80	4.20	0.80	1.90	3.90	0.42
IPC	June 1	4.45	3.05	0.55	1.62	3.20	0.10

In the spring of 1949, IPC was applied at a rate of 10 pounds per acre on April 25, harrowed lightly into the surface soil and good quality sheared sugar beet seed planted immediately. Planting of the beet seed was at two rates, a medium one of 4.3 pounds per acre and a light one of 2.3 pounds per acre. A few days after planting a heavy rain occurred and storm water from the city streets flowed over one replication of the test. Seedling emergence of both weeds and beets on the IPC treated plot which

[1] Scientific Journal Series No. 324, Colorado Agricultural Experiment Station.

[2] Agronomist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

[3] Investigations of the Division of Sugar Plants at Fort Collins, Colo., are cooperative with the Agronomy Section of the Colorado A & M Agricultural Experiment Station, and the experiments reported in this paper were conducted on the Agronomy farm of the latter agency.

[4] Mitchell, John W., and Paul C. Marth, "Sensitivity of grasses and some crop plants to Isoproply-N-Phenyl Carbamate." Science 106:15-17, July 4, 1947.

[5] Deming, G. W.—"Progress Report on Weed Control Studies at Fort Collins, Colorado." —Proceedings of the American Society of Sugar Beet Technologists, 1948, pp. 435-444.

was flooded was comparable to the check plot of the same replication. Therefore, data from the flooded replication are excluded from this report.

Counts of weed and beet seedlings were made on May 18 and a second count made on the IPC-treated plots on June 1. There were 20 counts per plot of a 4-inch by 12-inch quadrat centered lengthwise of the beet row. On May 18 the beet seedlings were beginning to show the first pair of true leaves. Those on the check plots were vigorous and making normal growth while the beets on the IPC plots were pale green and generally of smaller

TABLE 2. Stands, acre yields and percentage sucrose; IPC treated and check plots at Fort Collins, Colo., 1949. Data given as 2-plot averages.

Treatment	Harvested roots per 100′ of row	Acre yields		Percentage sucrose
		Gross sugar	Roots	
	(number)	(pounds)	(tons)	(percent)
Seeding rate 4:3 pounds per acre of sheared sugar beet seed.				
Check	88.5	6045	18.09	16.72
IPC	101.3	6582	19.34	17.00
Seeding rate 2.3 pounds per acre of sheared sugar beet seed.				
Check	80.6	6848	19.88	17.20
IPC	64.6	5950	17.58	16.92

size. A few were somewhat distorted. On June 1 the check beets had 4 to 6 true leaves and were growing vigorously and the IPC beets were about half the size of the checks, had a better color than on May 18 and now appeared to be making normal, though delayed growth. Weed and beet seedling counts are summarized as 2-plot averages in Table 1. In this test it is probable that the chemical had ceased to affect the growth of sugar beet seedlings at about four weeks after its application. When seedling counts were made, all living weeds were counted. Some dead weeds were observed on the treated plots and many of the living weeds were pale and making weak growth. When thinned, the treated plots were considered by the laborers to be essentially clean and the check plots moderately weedy.

The treated plots were thinned June 9. Since the initial stands appeared to be slightly thin, particularly on the plots seeded at the 2.3 pound seeding rate, a special effort was made to leave the best obtainable thinned stands. Rains delayed thinning of the check plots until June 16 and probably somewhat less care was used in thinning the checks. Thus it is probable that the treated plots were slightly favored, both in quality and timeliness of thinning.

On June 9, when the treated plots were thinned, most of the beet plants were showing marked recovery from the poor color and slow growth which had been so apparent in mid-May. By July 1, the beets on these plots appeared to be equal in growth and vigor to the checks.

This test was harvested in early October and the harvest results are given as 2-plot averages in Table 2. Considering first the 4.3 pound seeding rate, the difference in stand in favor of the IPC treated plots is probably attributable to the better thinning job done on these plots. However, in general, in this test there were no obvious differences in yield between plots having harvested stands of about 80 beets per 100 feet of row or better.

The differences in yield of roots and gross sugar and sucrose percentages between the treated and check plots seeded at this rate are probably not attributable to the treatment.

When the harvest data from the plots seeded at the 2.3 pound seeding rate are examined it is apparent that the IPC treatment reduced stands and that this resulted in a definite reduction in yield.

Treatment with IPC appears to have had no effect upon quality of the crop as measured by sucrose percentage.

Conclusions

IPC applied dry and worked lightly into the surface of the soil at rate of 10 pounds or more per acre just before planting sugar beets has given excellent control of both monocotyledonous and broad-leaved weeds which would normally have germinated at the same time as the sugar beets.

In the trials of previous years, the chemical has reduced emergence of sugar beet seedlings and has appeared to retard the early growth of those which did emerge. However, in 1949, with excellent conditions for emergence and early growth, the 10-pound surface application of IPC just before planting gave adequate thinned stands and a yield at least as good as the untreated check when the seeding rate was 4.3 pounds of sheared sugar beet seed per acre. When the seeding rate with sheared seed was light, 2.3 pounds per acre, the stand on the treated plots was only about two-thirds that of the untreated plots, and the root yields were apparently considerably reduced.

These results warrant further trials of this chemical as a pre-emergence treatment of the soil for control of weeds in the pre-thinning period of the sugar beet crop.

Effects of 2,4-D on Sugar Beets

O. A. HOLKESVIG[1]

Controlled field tests show that 2,4-D remaining in the soil after an application of this chemical may cause injury to seedling stands of sugar beets. This is especially true in areas where the rainfall is light and the chemical remains in the soil. Therefore, its application to sweet clover or other legumes at time of plowing under to prevent volunteering, or spraying of weeds in the fall, is a practice which should not be encouraged if subsequent injury to seedling beets or other crop seedlings is to be avoided. Such spraying as is done should be undertaken at a time when weeds or plants to be controlled through spraying are in a proper growing condition for most effective control.

TABLE I. EFFECT OF 2,4-D ON BEET WEIGHT AND SUCROSE PERCENTAGE
(Grafton, North Dakota)

	2,4-D Sprayed Fields			Unsprayed Fields		
Week	Avg. Wt. Lbs.	% Sugar	Purity	Avg. Wt. Lbs.	% Sugar	Purity
Sept. 10	1.16	10.9	75.4	1.05	16.2	83.3
Sept. 15	1.61	11.5	75.7	1.67	16.0	82.7
Sept. 24	1.27	13.5	85.8	1.44	17.7	91.5
Sept.30	1.56	13.5	86.3	1.72	16.8	86.2
AVERAGES:	1.38	12.2	80.3	1.45	16.7	85.9

The purpose of this article, however, is not to discuss weed control, but rather to point out the dangers arising from careless and indiscriminate use of herbicides and drift damage from same to sugar beets. That this is of more than academic interest is substantiated by reports of injury to many hundred acres of beets during the three years just past, in different parts of the United States, where sugar beets are grown as a commercial crop.

In 1947, reports were received from California of injury to seedling beets in fields adjacent to drain ditches which had been sprayed with 2,4-D to control willow trees. Many of the beet seedlings were killed outright and those which did survive showed typical malformational symptoms. Due to drastically reduced stands of beets, the tonnage yield of beets harvested was 18% below the average yield of the unsprayed portions of the same field.

In 1948, in the East Grand Forks, Minnesota area, a field of young beets was injured severely by 2,4-D application made to an adjoining grain field for the control of mustard. The drift damage killed many of the recently thinned beets, resulting in an appreciably reduced beet tonnage yield from the affected portion of the field. Although redress was sought in court by the injured party, the merits of the case still are undecided.

In 1949, more than 300 acres of sugar beets in the Grafton, North Dakota, area were injured severely by an apparently contaminated spray of toxaphene applied to beets in late August for the control of sugar beet webworm. Whether the containers were contaminated with 2,4-D is not known

[1] Manager American Crystal Sugar Company, East Grand Forks and Moorhead, Minnesota.

definitely, but the after-effects of the spray were typical of this material. To ascertain the extent of damage, samplings of affected and unaffected beets were taken each week for weight comparisons and determinations of sucrose percentage. The average results of these tests is shown in Table I.

The beets affected by the contaminated spray were extremely fibrous and difficult to slice, requiring many knife changes in slicing of these beets. In fact, many beets were so woody that it was impossible to process them. The resulting pulp was also very stringy, resembling excelsior rather than typical beet pulp. Also, the percentage sucrose in the beet was adversely affected.

In the Gothenburg, Nebraska, area, drift damage from 2,4-D spray was observed in a beet field adjoining an open drain ditch which was sprayed in mid-July for the control of weed plants. Samples were taken weekly of beets from the affected and unaffected portions of the field and are shown in Table II.

TABLE II. EFFECT OF 2,4-D ON BEET WEIGHT AND SUCROSE PERCENTAGE

(Gothenburg, Nebraska)

	Drift Damaged Field		Not Damaged Field	
Week	Avg. Wt. Lbs.	% Sugar	Avg. Wt. Lbs.	% Sugar
Sept. 9	1.41	12.9	1.67	13.1
Sept. 16	1.29	13.4	1.70	14.0
Sept. 23	1.49	13.7	1.94	14.5
AVERAGES:	1.40	13.3	1.77	13.8

The results indicate that while there was a depressing effect on the percentage sucrose in the beet, beet yield was more adversely affected. No record was available in this instance of the manufacturing worth of these beets, as the tonnage was too small to permit observation in the factory.

From the observations reported in this paper, it is apparent that 2,4-D damage to sugar beets varies according to the age of the plant. Assuming a normal concentration of 2,4-D material in spray applications, the drift damage to young beets is reflected in reduced stands of beets and consequent reduction in beet tonnage yield. When beets are injured by 2,4-D in mid-July, the tonnage yield is more adversely affected than the percentage sucrose in the beet. Where injury to beets is sustained from 2,4-D in August, the percentage sucrose in the beets is very materially depressed. Judging from the information at hand and from sectioning affected beets, regardless of time when injured, it is safe to conclude that, because of the fibrous nature of the beets, they are not desirable for sugar processing operations.

Considering the fact that in many instances the farmer is an innocent victime of careless handling of these spray materials, cognizance is being taken of this situation in some states by the promulgation of laws aimed at correcting abuses. Operators who engage in the application of these chemicals must have necessary training, registered materials and proper equipment for compliance with legal requirements. Aircraft used for spraying must have license for its operation. Drip-proof nozzles must be provided and the aircraft operated under wind velocities less than 10 miles per hour and flown not higher than 10 feet above the ground if the wind velocity is more than 5 miles per hour.

The above are some of the controls now being written into law in several states. This action is sorely needed in other states where flagrant abuses of proper precautionary measures have been a common occurrence and where redress by law is not had because of lack of legislation covering the field of operation. It would appear that concerted action of groups of individuals as an association would accomplish much by way of educating the careless operator in regard to the need of proper precautionary controls. Regardless of action taken, it is obvious that the use of 2,4-D must have intelligent and restricted application if detrimental experiences encountered to date are not to be repeated on a much more wide-spread scale.

Weed Control Studies on Sugar Beets[1,2]

VIRGIL H. FREED AND RAY A. PENDLETON[3]

Introduction

Weed control in row crops such as sugar beets is one of the major problems of production. Hand weeding is slow and too expensive for extensive operations. As a consequence there is a need for a cheap, economical method of weed control. Chemical weed eradicators offer a possibility of realizing this end.

Trials on sugar beets have demonstrated the very limited value of present day selective herbicides for weed eradication in this crop. Certain plasmolytic, inorganic salts solutions such as sodium chloride or sodium nitrate are the only ones sufficiently selective to be useful. However, pre-emergent weed control with suitable contact sprays has been demonstrated to be effective. The weed problem in beets in Oregon varies with the season of the year when the beets are planted.

Materials and Methods

The weeds commonly encountered in late summer planted beets for seed production include:

Annual rye grass	*Lolium multiflorum*
Annual blue grass	*Poa annua*
Hairy vetch	*Vicia villosa*
Chickweed	*Stellaria media* and *Cerastium vulgare*
Groundsel	*Senecio vulgaris*
Pigweed	*Amaranthus retroflexus*

Spring planted crops for sugar production will usually have such weed problems as:

Lambsquarter	*Chenopodium album*
Pigweed	*Amaranthus retroflexus*
Mustard	*Brassica arvensis*
Mallow	*Malva rotundifolia*
Radish	*Raphanus raphanistrum*
Annual bluegrass	*Poa annua*
Barnyard grass	*Echinochloa crusgalli*
Green Foxtail	*Setaria viridis*

Chemicals selected for trial at the different times must, as a *priori*, be chosen for their property of controlling the weeds present. It does not necessarily follow that one chemical will be effective on all weeds. Consonantly, the following trials were conducted with this in mind.

Trial 1. Pre-emergent treatments on Spring Planted Sugar Beets—

The seed bed for planting was prepared sufficiently ahead of time to

[1] For presentation at the Sixth General Meeting of the American Society of Sugar Beet Technologists, Detroit, Mich., Feb., 1950.

[2] Published as Technical paper No. 618 with the approval of the Director, Oregon Agricultural Experiment Station and Chief, U. S. Bureau of Plant Industry, Soils and Agricultural Engineering, on the basis of research conducted cooperatively.

[3] Associate Agronomist, Oregon Agricultural Experiment Station, and Agronomist, Division of Sugar Plant investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U.S.D.A.

favor germination of weed seed. Planting of sugar beets was made June 28, 1949, in rows spaced 20 inches apart with seeding at the rate of about 10 pounds per acre. Eleven days after planting, trials were established in a thrice replicated randomized complete block in plots of 8 rows 10 feet long. Eleven treatments were used, including 2 rates of a sodium salt of 2,4-D; 3 rates of TCA (trichloroacetic acid); 3 rates of emulsifiable IPC (isopropyl N-phenyl carbamate); one rate of Shell 20; one rate of a mixture of Dinitro general and diesel oil; and an untreated check. Four weeks later, four random .0001 acre quadrat counts of weeds per plot were taken and four random 2 foot segments of row were counted for stand.

TABLE 1. PRE-EMERGENT SPRAYS ON SPRING PLANTED SUGAR BEETS.

Material	Rate per acre	Beet plants per 100 feet of row[1]		Weeds per .0001 acre[2]	
		number	% of check	number	% of check
Sodium salt of 2,4-D	1.0 lb. a.e[3]	575	76.6	12.5	49.5
Sodium salt of 2,4-D	1.5 lb. a.e.	655	87.3	6.5	25.7
Ammonium salt of TCA (trichloro-acetic acid)	10.0 lb. a.e.	680	90.7	19.9	78.9
Ammonium salt of TCA	20.0 lb. a.e.	725	96.6	17.4	69.0
Ammonium salt of TCA	40.0 lb. a.e.	640	85.3	12.5	49.6
Emulsifiable IPC	2.0 lb.	770	102.6	20.9	82.9
Emulsifiable IPC	4.0 lb.	895	119.3	24.2	96.0
Emulsifiable IPC	8.0 lb.	815	108.6	18.5	73.3
Shell 20	80 gal.	245	32.6	1.4	5.5
Dinitro general	1 qt.)				
Diesel oil	20 gal.)	805	107.3	4.0	11.8
Untreated check	—	750	100.0	25.2	100.0

[1] Average from 3 plots, four counts of 2 foot row segments per plot.
[2] Average of 3 plots with three quadrat counts per plot.
[3] a.e. = Acid equivalent.

Trial 2. Selective grass control in fall planted beets—

As previously indicated, fall germinated grasses often are extremely troublesome in beets planted for seed. Preliminary trials had indicated that established beet seedlings of 4 to 6 leaf stage are tolerant of rates up to 5 pounds IPC per acre. Germinating beets will tolerate only up to 2 pounds per acre of IPC.

A trial was established in October of 1948 on beets which had been planted in early September to determine the feasibility of using IPC in the fall for grass control. Four row plots 10 feet long were established in randomized block design with 3 replications. Treatments consisted of 3 rates of wettable IPC, 3 rates of emulsifiable IPC and 3 rates of a mixture of emulsifiable IPC and diesel oil. At the time of treatment the beets had from 2 to 6 leaves and ranged up to 4" high.

Results and Discussion

The results of the effect of pre-emergent chemical treatments on both weeds and beets are summarzed in Table I. These treatments were applied at volumes of 40 gallons per acre with the exception of two as noted in Table 1.

The Dinitro (3,5 dinitro-O-secondary butyl phenol) general and diesel oil proved to be the best all around treatment. The beet stand on this plot averaged 107.3% of the check while giving a weed control of 88.2%.

The Shell 20 (an aromatic oil) gave the best weed kill but the "heavy ends" of this oil remained as a residue sufficiently long to kill emerging beet seedlings. Such has often been found true in pre-emergent use of oils possessing high boiling fractions.

The sodium salt of 2,4-D was quite effective in reducing the population of weeds and the remaining plants exhibited typical symptoms of 2,4-D poisoning. Even though there was no rain subsequent to the application,

TABLE 2. SELECTIVE GRASS CONTROL TRIALS IN SUGAR BEETS FOR SEED.

Material	Rate per acre	Weed control[1]	Observed effect on beets[2]
	pounds	percent	
Wettable IPC	1	50	none
Wettable IPC	3	85	none
Wettable IPC	5	95	slightly retarded
Emulsifiable IPC	1	60	slight necrosis
Emulsifiable IPC	3	90	necrosis and retardation
Emulsifiable IPC	5	98	20% necrosis
Emulsifiable IPC+	1)		
Diesel oil	5 gal.)	90	slightly retarded
Emulsifiable IPC+	3)		(20% necrosis
Diesel oil	5 gal.)	95	(growth retarded
Emulsifiable IPC+	5)		(40% necrosis
Diesel oil	5 gal.)	100	(growth retarded

[1] Estimated control. Weeds mainly annual ryegrass and annual blue grass.
[2] Observations of two replicates December, 1948.

the beets showed strong symptoms of 2,4-D toxicosis and many of them were killed outright.

The ammonium salt of Trichloro-acetic acid (TCA) was reasonably effective in killing most kinds of weeds that were present even though it is used primarily as a grass killer. The beet stand was not reduced seriously by this material, although it is suspected that had there been more moisture in surface soil more injury may have resulted.

IPC, at the rates tried, proved innocuous to the beets in this trial and as was anticipated did very little harm to the broadleaved weeds present. It has been found that IPC, while nearly specific for grasses, will supress many dicotyledonous plants at time of germination. Soil moisture is perhaps the most critical factor in determining the effectiveness of IPC. If moisture is deficient the IPC has little or no effect. Conditions favorable to accelerated microbiological activity in the soil, such as optimum moisture and high temperature, speed the decomposition of IPC, likewise lowering its effectiveness.

Table 2 gives a summarization of the results obtained with IPC applied to sugar beets in the fall. No data on these plots were obtainable the following spring as unusually severe winter weather froze out the beets.

It will be noted that in general the three-pound rate of IPC gave satisfactory control of the weeds with a minimum effect on the beets. The five-pound rates of the emulsifiable IPC plus five gallons of diesel oil resulted

in injury to the beets whereas the wettable IPC at 5 pounds gave only a slight retardation of growth.

Field treatments of sugar beets were made with wettable IPC in the falls of 1948 and 1949 for grass control. The acre rate of application ranged from 4 to 10 pounds of actual IPC on beets having from 4 to 12 leaves. The results to date have been very satisfactory. Dosages of 4 to 6 pounds of IPC per acre have proven sufficient to give good grass control if applied before the tillering stage of the grass. Dosages above 6 pounds per acre or lesser amounts applied before the beets attained the four-leaf stage resulted in retardation of growth. However, the beets generally overcame this within a few months.

Summary and Conclusions

Weed control trials on sugar beets have indicated that this crop is very limited in its tolerance to chemicals. Pre-emergent treatment with suitable chemicals affords one of the best means of minimizing this problem.

Dinitro alkyl phenols with diesel oil gave promise of being one of the more satisfactory materials. The sodium salt of 2,4-D, while giving fair weed control, has too long a residual effect. Heavy aromatic oils are unsatisfactory for the same reason. In order to use such an oil, it would be necessary to assure a greater lapse of time between application and emergence to permit disappearance of the residue.

IPC has shown much promise for controlling grass in fall planted beets. The beets have shown considerable tolerance to this material after passing the four-leaf stage. Soil moisture is the most important limiting factor in using IPC.

Latest Developments in the Use of Herbicides for Selective Weed Control in Sugar Beets

B. H. GRIGSBY AND L. M. STAHLER[1]

Research on the use of herbicides in sugar beet weed control has been along two lines, pre-emergence treatments and post-emergence selective sprays. Numerous difficulties are encountered in both lines of work and results to the present time have been somewhat less than satisfactory from the standpoint of enabling us to formulate field practices which could be recommended for grower usage. It is our purpose, in this paper, to present a progress report and indicate some of the methods which are being employed to solve some of the many problems that exist in this phase of weed control.

The data on which this paper is based are the results from cooperative and somewhat uniform investigations by a number of investigators in the central United States and Canada. These include USDA, state experiment station and commercial representatives. The writers wish to express appreciation for the generous cooperation of all who have had a part in these investigations.

Results of investigations on selective sprays have been, in the past two seasons, uniformly disappointing. The beet foliage is sensitive to most chemicals and any material which is active as a herbicide is likely to be active on beet leaves. Certain chloride salts are exceptions to this statement, however, and the only reports of success have been from the use of sodium chloride and potassium chloride. These two compounds are the only materials which can be suggested for grower usage and they have some very definite limitations. The degree of weed control and possibility of injury to beets are largely dependent upon weather conditions at, and preceding, the spray application. In any case, high rates of application, 200-400 pounds per acre, are necessary and these require large volumes of water to form a solution of the salt. When the potassium salt is used approximately one-half as much salt is used as compared to sodium chloride. Young beets, or older beets sprayed at high pressures, may be injured or killed by salt spray. Weeds which are too tall, 4-8 inches, or weeds which, because of peculiar growing conditions, have become hardened are not seriously affected by salt spray. Some of the data which we have seen would indicate that, in sugar beets, salt spray should be classified as an unsatisfactory method of weed control.

Copper compounds which are known to cause injury to beet foliage, but because of possible stimulating effects of copper were considered for selective spraying, gave very poor results in 1949. When quantities sufficient

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Agronomist, Bureau of Plant Industry, Soils and Agricultural Engineering, Brookings, South Dakota, respectively.

to kill large weeds were applied a considerable reduction in beet stand was produced. Surviving beets, however, do make a rapid recovery and grow in a normal manner. Copper compunds and zinc sulfate do not appear suitable for commercial use.

The major part of the investigations in 1949 dealt with pre-emergence treatments at East Lansing and at Fargo, N. D. The results of these tests, and data from prior seasons, have enabled us to eliminate certain groups of herbicides from consideration in beet weed control problems. All forms of 2,4-D, when applied as pre-emergence treatments, have reduced the beet stand to a marked extent and have given only fair weed control. Borax and boraxchlorate combinations, likewise, appear to be of little value. The quantities, at least 320 pounds per acre, required for weed control reduced the beet stands and affected the vigor of the beets. Cyanamids, which have been used successfully in corn and some vegetable crops, have not, in two seasons work, shown any promise for use in beets. In fact, they have affected growth and vigor of neither beets nor weeds.

One interesting development concerning the choice of diluent for pre-emergence sprays was apparent at both stations in 1949. In previous seasons most herbicides used for pre-emergence treatment were applied in water

TABLE 1. Screening test rating of selected herbicides applied when sugar beets were in four to six leaf stage on June 11. Estimates of stand and vigor made six weeks later. Brookings, South Dakota, 1948.

Herbicide	Rate in Lbs.	Tolerance rating on sugar beets			Herbicidal rating on weeds					
					Grass weeds[1]			Broadleaved weeds[2]		
used	per acre	Stand	Vigor	T.R.	Stand	Vigor	H.R.	Stand	Vigor	H.R.
E.H. 1*	2	90	70	630	90	80	280	100	100	0
E.H. 2*	2	90	80	720	60	50	700	100	100	0
Check	....	100	100	1,000	100	100	0	100	100	0
E.H. 1	4	80	40	320	60	60	640	100	70	300
E.H. 2	4	80	70	560	50	40	800	100	50	500
LFN—472**	¼	0	0	0	100	100	0	20	80	840
LFN—472	½	0	0	0	90	90	190	2	80	980
EC. 3740***	2	100	100	1,000	5	20	900	100	100	0
E.C. 3740	4	100	90	900	0	0	1000	100	100	0
Check	....	100	100	1,000	100	100	0	100	100	0
E.C. 3441***	2	80	70	560	40	60	760	90	80	280
EC. 3441	4	80	40	320	10	60	940	90	50	550
E.C. 3221	2	100	100	1,000	60	80	620	100	100	0
E.C. 3221	4	100	70	700	40	60	760	100	60	400
E.H. 1	1	100	100	1,000	100	100	0	100	100	0
E.H. 2	1	100	100	1,000	100	70	300	100	100	0
Check	....	100	100	1,000	100	100	0	100	100	0
E.C. 3740	½	100	100	1,000	100	80	200	100	100	0
E.C. 3740	1	100	100	1,000	90	60	460	100	100	0
IPC	2½	100	100	1,000	100	100	0	100	100	0
IPC	5	100	100	1,000	100	100	0	100	100	0
Check	....	100	100	1,000	100	100	0	100	100	0
IPC	10	100	70	720	80	80	360	100	100	0
IPS	20	100	40	400	60	30	720	100	80	200

[1] *Setaria spp., Echinochloa spp., Panicum spp., Avena fatua.*
[2] *Amararthus spp., Chenopodium spp., Kochia spp.*
* Carbide and Carbon Chemicals.
** 2,4-D, finely divided acid.
*** Sharpels Chemical Co.

and many gave only indifferent results. In 1949, however, a number of compounds were applied both as water and oil sprays and considerable difference in effect was observed. Dinitrophenol, pentachlorophenol, IPC and xanthogen disulfide were all much more effective as weed killers when applied in 40 gallons of diesel fuel per acre. At East Lansing, IPC, which had been considered worthless in other seasons, was one of the most satisfactory materials in the tests when applied in oil. This observation of increased toxicity when applied in oil indicates that further study of this method of application must be made. The possibility that a longer residual action by the chemical, but not extending sufficiently long to injure beet seedlings, exists should not be overlooked

When the entire experimentation is considered it is apparent that no material has been found which is entirely satisfactory for grower use in a pre-emergence weed control program. Dinitrophenols were too toxic to beets in many cases, although one or two of the stations got promising results on a few weed species. A rate of less than 2 pounds per acre is necessary to avoid injury to beet seedlings.

Pentachlorophenol, in oil, was not uniformly satisfactory in performance in 1949. At East Lansing the results indicated a fair degree of weed control without serious injury to beet stands. The experience of certain Michigan vegetable growers, in which complete loss of the crop followed the use of this compound, should be kept in mind when recommendations concerning pentachlorophenol are made. There appears to be some relation between

TABLE 2. Tolerance rating and herbicidal rating of selected herbicides applied as pre-emergence treatments on sugar beets at Brookings, South Dakota.

Chemical	Rate in Lbs.	Sugar beets			Annual grass			Broadleaved weeds		
used	per acre[1]	Stand	Vigor	T.R.[1]	Stand	Vigor	H.R.	Stand	Vigor	H.R.
1. E.H. 1	2	50	90	450	100	60	400	62	70	570
2. E.H. 1	4	56	80	448	100	60	400	56	65	640
3. E.H. 2	2	98	90	882	12	40	950	78	80	380
4. Check	....	100	100	1,000	100	100	0	100	100	0
5. E.H. 2	4	100	90	900	15	30	950	50	80	600
6. LFN—472	1	52	5	260	42	40	580	8	15	990
7. LFN—472	2	12	5	60	38	40	620	4	15	996
8. E.C. 40	2	98	100	980	12	20	875	100	100	0
9. E.C. 40	4	92	100	920	16	10	970	100	100	0
10. Check	....	100	100	1,000	100	100	0	100	100	0
11. E.C. 41	2	82	100	820	74	70	480	84	100	160
12. E.C. 41	4	70	90	636	60	40	760	94	100	60
13. E.C. 21	2	100	100	1,000	76	80	390	88	100	120
14. E.C. 21	4	88	100	880	100	50	500	100	100	0
15. XP 40	5	100	100	1,000	88	100	120	48	90	570
16. XP 40	10	74	80	592	80	50	600	54	75	600
17. Check	....	100	100	1,000	100	100	0	100	100	0
18. Polybor	320	86	75	602	48	50	760	100	20	800
19. Polybor	640	88	40	352	41	20	920	100	10	900
20. IPC	5	100	95	950	74	30	780	100	100	0
21. IPC	10	100	90	900	48	30	860	100	100	0
22. Check	....	100	100	1,000	100	100	0	100	100	0
23. Cyannate	100	90	70	630	100	100	0	62	100	380
24. Cyannate	200	54	40	216	100	100	0	64	100	360

[1] T.R.—Tolerance rating
[2] H.R.—Herbicidal rating

climate and soil factors and crop injury, the exact nature of which has not been determined.

TCA, which appears to offer some possibility for weed grass control, was not considered satisfactory at East Lansing. At Fargo, however, rates of 10 and 20 pounds per acre gave the best weed control of any compound tested and only slightly reduced the beet stand. At the East Lansing station effective weed control was not observed at any rate which would permit beet emergence. Good weed control was obtained in the Manitoba trials but vigor of beets was considerably reduced. Experiments in some of the North Central states with other crops lead us to believe that, in some soils and under some moisture conditions, residual toxicity from TCA may be a serious matter and that field scale use of TCA is hazardous. The use of TCA for the control of patches of quack grass in beet fields is a different matter and it can be recommended.

A number of new herbicides were tested at most of the stations in 1949. Many of these were thought to be of value in the control of grass seedlings. The results were inconclusive at Fargo and at East Lansing, probably due to the fact that the plots at both stations did not have weed grasses in any significant amount. At Brookings dichloral urea, maleic anhydride and certain hydrophthalic acid derivatives were highly specific for grass weeds and had little effect on beets and broad-leaved weeds. While the results are preliminary, there is reason for considerable hope that one or more of these compounds may come to be of great value in seasons and areas where grass weeds are important.

Research in sugar beet weed problems, as in other crop areas, is seldom able to keep up with the large number of new herbicides, or possible herbicides, which are available from the chemical industry. Research workers generally have limited time and space and can apply only a certain number of compounds in trials which are replicated enough to give reliable data. Consequently, rather large amounts of experimental materials are distributed for trial but never reach the field. Laboratory shelves, or possibly small, token applications, are the ultimate fate of many lots of chemicals. This condition is undesirable because it represents considerable waste and undue pressure on research facilities.

A need for some adequate screening procedure for chemicals before they are placed in field trials has been apparent for some time. In 1949, the Brookings station established a screening technique which promises to be of much value in eliminating some compounds and indicating possible types of field trial which should be made on others. Essentially, the method consists of using small, replicated plots to secure weed populations of a representative type, planting one or more types of crop plants and then applying the chemicals of unknown herbicidal value. A stand determination for the crop plants and an estimate of apparent vigor is made. Each of these values is expressed as a percentage of the untreated check plots. The two values are then multiplied, the product divided by ten and designated the "crop tolerance," or C. T., value. Similar determinations are made for the various weed species and the product subtracted from 1,000 to give a positive value. This value is considered the "herbicidal rating," or H. R., for

the compound used. In evaluating compounds, if the C. T. rating is less than 800 and H. R. less than 700 the material is rated as unsatisfactory for field trials. Other details of this screening procedure were reported at the North Central Weed Control conference at Sioux Falls and are available in the Proceedings of the Conference.

This method of screening products represents a considerable saving of time and we believe that this, or some other reliable type of screening, should be the forerunner of extensive field trials of herbicidal materials. Where regional problems are involved such an approach gives data which are comparable and enable investigators to readily evaluate a compound and, in connection with adequate climatological data, facilitate study of variations due to climatic factors.

In conclusion, we should like to emphasize the fact that, in much of the sugar beet producing area, weed problems are seasonal in nature. In dry seasons, where temperatures are normally high, weed control can be accomplished by mechanical methods. However, in wet, cool springs, and these occur frequently in parts of the area, mechanical control is not effective. It is under the latter conditions that selective chemical herbicides are needed, especially in areas where grasses are the most important part of the weed population.

While it is true that suitable chemical methods have not yet been found, we believe that there is room for considerable optimism in regard to the eventual development of a system of tillage combined with chemical methods which will greatly facilitate mechanization of the spring phases of sugar beet production.

Control of Annual Grasses in Sugar Beets

L. E. WARREN[1]

Weeds have presented to the sugar beet grower a problem which has been attacked for many years by cultivation and hand hoeing. Hoeing often has proved to be unreasonably expensive and sometimes unreliable. Also, the desirability of cultivation, for other than weed control purposes, is questionable. However, these have been the only means known to eliminate or reduce the harmful weed population between and in the rows.

Recently beet growers have made increasing use of general contact chemicals for weed control as pre-emergence sprays to kill weeds which emerge ahead of the beets, as well as selective sprays to kill the weeds in growing beets. These both have been valuable, but since later germinating weeds usually reduce the benefit of pre-emergence treatments, and selective sprays are not effective on grasses, it is still necessary to find a control of annual grasses in growing beets.

Grasses, as well as other weeds, not only compete with the beets for nutrients, water and sunlight, but interfere with harvest operations. Considerable expense often has been incurred by the grower in removing these weeds only to have the field reinfested by harvest time. It is conceivable that grasses could be eliminated from sugar beets by (1) a selective chemical which would not harm the beets, or (2) a general contact spray, placed so that the beets would not be injured, completely covering the soil surface between and in the rows.

A New Selective Herbicide

A newly introduced grass killer called STCA (sodium trichloroacetate[2]) promises to aid considerably in our fight against annual grasses. This chemical, which is easily soluble in water, attacks the grasses through their roots, and, therefore, must be present in the soil to be effective. At the rates needed STCA will not injure sugar beets at any growth stage under conditions tested so far whether used as an overall spray or placed below the leaves.

Trials last summer were conducted at the Dennis Leary ranch at Ryde, the Gene Winters ranch at Woodland, and others in cooperation with the Spreckels Sugar Company. Application of STCA was made by ground sprayer at intervals of a few hours to several days prior to either rain, sprinkling, or furrow irrigation. The watergrass, which was the predominant weed in these fields, was in all growth stages. STCA up to 16 pounds per acre was applied to all stages of sugar beets from before emergence to nearly full grown.

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[1] Agricultural Research Specialist, Dow Chemical Company.
[2] Rates per acre will refer to acid equivalent, not marketed product.

Best results were obtained in these tests with 6 to 8 pounds of STCA per acre applied before germination of the grasses or while they are less than 2" high, and when irrigation followed application within 3 to 4 days. A slight marginal leaf burn from overall sprays at higher temperatures was the only observable effect on the beets. These trials were conducted on

Figure 1.—Late-emerging watergrass covered the ground under nearly mature beet foliage. This is a typical condition, and can ruin a beet crop unless controlled.

medium textured soils; because of leaching, lighter soils may require somewhat more than 6 to 8 pounds of chemical, but good control should be obtained with these dosages on heavier soil types.

Shielded Spray Developments

The culture of beets, including their response to chemicals, has shown them to be very hardy plants after they have reached the 5- to 6-leaf stage. The leaves may be severely damaged by cultivation, rolling or sprays, but the

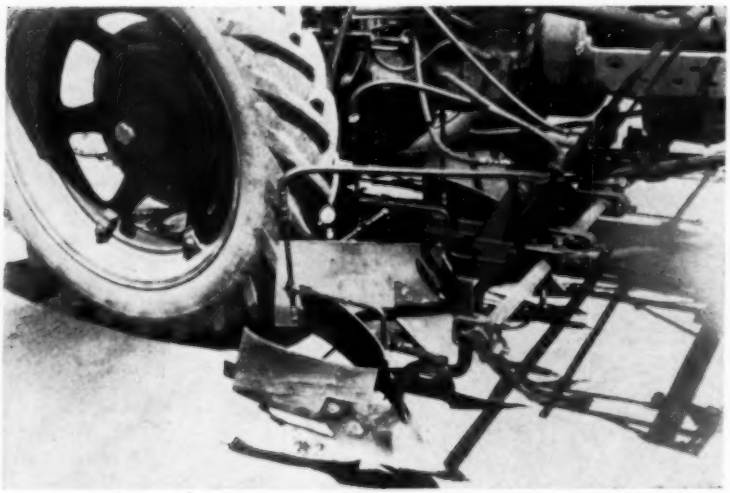

Figure 2.—Shielded Spraying of late-emerging watergrass was accomplished with this combination of winged furrowing shovels and spray nozzles.

crop recovers quickly, with no effect on the root development. Because of this plans were made to test the effect of directing a contact chemical spray to cover the complete soil surface below the beet leaves.

In other phases of the trials mentioned previously, it was learned that beets in good growing condition had to be about 14" high before they would stand a contact spray which could kill young grasses. Therefore, shields were used to protect the younger beets. With these shields, nearly a direct spray was necessary to cause more than a leaf burn on the crop after the 5- to 6-leaf stage.

In a field of nearly full grown beets near Davis, the following treatments per acre were applied to a thick stand of very young watergrass. (See Fig. 1).

1 qt. of Dow General[a] in 40 gallons of diesel oil (no water)

1 qt. of Dow General in 25 gallons of diesel oil added to 25 gallons of water (plus wetting agent)

The sprays were placed so they overlapped across the rows beneath the leaves.

[a] Dinitro sec-butyl phenol 55%.

The Dow General in oil alone seemed slightly superior to the emulsion spray, but both proved effective.

The equipment to apply this test was arranged by Austin Armer of Spreckels Sugar Company. Shields to lift the beet leaves above the spray consisted of 10" ditching shovels fitted with 24" strips of belting held against the beet leaves by pieces of spring steel on the lower side. The nozzles were suspended on special pipe supports behind these shields for adequate protection. Both shields and nozzle supports were attached to the center tool

Figure 3. Striking evidence of the effectiveness of shielded spraying of late-emerging water grass (left—untreated; right—shield-sprayed with fortified oil).

bar of a Farmall "M" tractor, and the power for the spraying operation was supplied by an Essick air power sprayer towed behind. The nozzles were at a height of 11" to 13" above the ground and directed downward, but placed so the edges of the fans overlapped to cover the bases of the beets. In other trials, the writer used duckfeet weeders with steel straps welded to extend back of the nozzles and to lift the leaves sufficiently. In still others, where the beets were younger, the shields were vertical and set to run as close to the row as possible, but yet provide adequate protection.

A grower can use any arrangement he has available which can perform the operation. The entire set-up can be mounted on the tractor if desired, using a 50-gallon drum for the tank, and the power take-off to operate the pump. Shields can be attached to the tool bar to coincide with the planter rows, as the cultivator does now.

For best control the grasses should be sprayed as soon as possible after emergence, but before they are 2" high. The weed control program in sugar beets could include STCA properly timed to the germination of the grass and irrigation at any time during the season, followed if necessary by another STCA spray or a contact chemical treatment.

Either the general contact or STCA treatment or both can be adapted easily to the normal culture of sugar beets with substantial savings. Naturally the present costs of producing a crop must be reduced by these new methods to make them attractive. Some of the costs involved are listed below in amounts per acre per treatment.

Treatment per acre	Cost per acre
1 qt. Dow General in 25 to 50 gal. Diesel Oil	$5.00 to $7.00
6 to 8 pounds STCA[4]	4.00 to 5.00

Other advantages which may be realized from this program are:

1. **Replaces hand labor with a more dependable operation.**
2. **Eliminates need for working ground while wet.**
3. **Prevents bringing more weed seeds to soil surface during season.**
4. **Does not break down beds as with cultivation.**
5. **Aids in reducing total weed seed population in the soil.**

As with any new program, if proper caution is not observed, either the chemical may fail or cause too much injury. In view of these possibilities and variations in local responses, it is suggested that only trial acreages be treated. In this way, the best use of the chemicals can be learned for each situation, and a good foundation will be laid for well-directed action the following year.

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[4]STCA can be applied with the above contact chemicals but the burn on the leaves and crown buds of the sugar beets will be increased.

Some New Ideas for Weed Control

HARVEY P. H. JOHNSON[1]

The Beet Sugar Development Foundation is entering its fifth year of cooperative study with the mechanical engineering section of the Colorado A & M Agricultural Experiment Station, Fort Collins, Colorado. Various mechanical implements have been used for weed control in the sugar beet crop during these past five years, the most popular being the tine weeder which has been used commercially on large acreages the past three years. This single machine has considerable merit. It should be recognized also that it does have limitations and that caution in its use should be exercised. These favorable and unfavorable factors of the tine weeder will not be discussed in this paper, as they have been covered fully in previous papers.

Within the past year several new implements have been used, some being new tools while others fall in the category of being new to the beet crop, having been used previously with considerable success on other row crops such as beans and corn. A discussion of these recent innovations is the scope of this paper. All of these tools require more experimental use; in fact, one has not yet been used in a sugar beet field.

In appraising new implements, simplicity in design ranks very high on the score card. Simplicity, in turn, makes possible a lower manufacturing cost, making the new item more attractive to the grower, the ultimate user. While simplicity is highly desirable, one must not hold it as the only criteria. The simple tools already in use fall short of giving the desired results. It seems reasonable, therefore, that one should also weigh the merits of the more complex machines carefuly. The more complex machine becomes a simple machine in popular opinion if the results are highly satisfactory.

The first machine to be considered is the cycloid weeder developed by the Colorado A & M Experiment Station. This unique device makes use of flexible tines arranged as two inverted baskets with the inside tines of each basket slightly overlapping. The machine is run so as to be directly over the row at the point where the two inverted baskets overlap. A ground-driven wheel furnishes the power. The cycloid action of the tines produces a rather gentle weeding over the beet row, increasing its cultivation toward the row center. This machine offers much possibility for early cultivation when the beets are in the 2- to 4-leaf stage. At this time the small emerging weeds can be destroyed in the beet row without injury to the beet. The crustbreaking potential of this machine should not be overlooked.

Another machine, perhaps equally efficient in early cultivation, is one patterned after a sugar cane weeder. Side-delivery rake tines were set perpendicular near the periphery of a 14" circular plate at three-inch intervals. Two of these plates are driven by the same wheel, making it a two-row unit. Experimentally it has been built as an adaptation to the Milton blocker. Plates can be adjusted to different angles over the row, thereby increasing or decreasing the severity of cultivation. Different size rake tines were also used, the heavier tines giving a more severe cultivation suitable to later cultivations. This tool was designed and built by the Beet Sugar Development Foundation.

[1] Statistician-Agronomist, The Beet Sugar Development Foundation, Fort Collins, Colorado.

It should be reemphasized here that all beet blockers are likewise weed removal tools. The percent of weeds removed approaches the portion of the beet row removed by the blocker. Several of these blockers have already been discussed, therefore will not be included here. The weeder attachments on these blockers warrant some attention. Replacing the tines with short blades or placing short blades on the end of the tine has been tried this past year with promising results. In addition to the many Dixie adaptations two additional ones were made by the Foundation, the first for the B & P blocker consisting of 18 small knives on a disc-shaped wheel. Cotton growers have taken to this innovation and a large number of the machines have been sold for cotton fields. The second modification has been for the Milton blocker, replacing the conventional blocker wheel with the small knife wheel.

Rotary hoes have been used in beet fields in previous years as crust breakers and to give light cultivations. The more recent larger wheels made for cotton and corn offer great possibility if run with the curve of the tooth turning into the ground. Speeds govern the severity of the cultivation; the faster the travel the more dirt is moved. Gangs of rotary hoe wheels can be set abreast and run over the beet row after the beets have reached the four-leaf stage. It is of interest to know that in the cotton fields this tool has proven the most desirable of any yet tried.

New ideas on within-the-row cultivation tools have also come to our attention. Most important in this category has been the use of a tool which has already been used with success in other row crops. The Culti-Cover made by the Russell Manufacturing company makes possible a cultivation program now used effectively near Toppenish, Washington, where bull tongues are used to cover up small emerging weeds in the beet row. This cultivator tool bar device consists of two shoes or blades—the front shoe set so as to push crust and weeds away from the beet row and leveling the ground for the rear shoes, which run slightly deeper and which are set to bring fresh moist soil back evenly around the beet plant, smothering those weeds not removed by the front shoe. With one of these tools on either side of the row the combined operation of the front and back shoes maintains an evenly hilled row and kills weeds between the plants in the entire length of row without much injury or disturbance to the sugar beet root system. The tool will work better at speeds above three miles per hour. It is especially adapted to later cultivations; however, experimental work this year will include its use in the earlier stages of growth as well.

Mr. Campbell, a grower in the Imperial valley in Southern California, used a disc to remove the weeds between the two rows planted on a single bed. This disc was run about an inch below the ground surface and was made with bearings which would permit its easy movement should weeds or clods build up on either side. This self-cleaning disc was doing an excellent job. Shields were placed on either side as close to the beet row as tractor driving would permit.

Chemical weed control still has possibilities even though it has not found extensive use in our beet-growing areas, including those areas where

it is most readily adaptable. This past season light 28-inch hoods were built to run over the row. This permitted the use of a higher pressure when the more volatile materials were used as the weed spray. This "fogging in" method proved very successful on a 40-acre tract near Longmont, Colorado, where cooperative work between the Great Western Experiment Station, a local weedicide dealer, Colorado A & M College and the Foundation made use of ordinary fortified diesel fuel to kill a healthy growth of voluntary grain and wild oats just prior to the beet emergence. Hoods make possible the use of a smaller amount of the oil and likewise aid in getting coverage down into the crown, which is so necessary in getting permanent kill on grasses.

Entomology

Soil Fumigation of Sugar Beets for the Control of Sugar Beet Root Maggot

VERNAL JENSEN AND C. P. PARISH[1]

The application of ethelene dibromide as a side dressing on sugar beets was used primarily by us for the control of sugar beet root maggot which has been prevalent in northern Utah and parts of southern Idaho at various intervals.

In 1948 a small test was made in southern Idaho using various concentrations ranging from 20 to 80 pounds per acre. When rates of more than 40 pounds were used, injury to the beets was observed. Although the injury was not always fatal, the tonnage was reduced materially, the beets being short with sprangled roots.

In 1949 approximately 100 acres were sidedressed the latter part of June, using from 10 to 20 pounds per acre. Besides effective control of the maggots, a rather striking stimulating effect resulted. Foliage became considerably darker and more vigorous.

Following are the average results from five fields where harvest data was collected:

Check:	**15.92% Sugar**	**13.6 Tons per Acre**
Treated:	**16.21% Sugar**	**16.4 Tons per Acre**

Although part of this tonnage increase was undoubtedly due to increased stands, the stimulating effect was evident from the vigor and color of the foliage and the increased size of the beets.

Two additional tests were conducted on fields showing rather severe injury from sugar beet nematode. Rates of 20 and 40 pounds per acre were applied.

Northern Utah

Check	**15.50% Sugar**	**9.74 Tons per Acre**
40 lbs.	**15.95% Sugar**	**12.26 Tons per Acre**
20 lbs.	**16.45% Sugar**	**14.32 Tons per Acre**

Southern Idaho

Check	**17.18% Sugar**	**16.87 Tons per Acre**
40 lbs.	**16.86% Sugar**	**17.28 Tons per Acre**
20 lbs.	**16.82% Sugar**	**21.17 Tons per Acre**

A four row digger type applicator mounted on a tractor with a pressure system using eight diggers on each side of row with duck feet or knives on the back bar to seal the digger openings was used. Depth of application was 5 to 6 inches.

A forty percent ethelene dibromide was diluted with white kerosene and made up to twenty gallons of solution per acre. This insured a more uniform rate of application and also eliminated the necessity of changing fumigator settings for the various rates.

We appreciate the fact that we probably do not have sufficient replicated data or results on various soil types and fertility levels. However, the stimulating effect was so noticeable on the above tests that we thought it advisable to present this data.

[1] The Amalgamated Sugar Co.

The Sugar Beet Nematode in Michigan

H. W. BOCKSTAHLER[1]

Occurrence of the sugar beet nematode (*Heterodera schachtii* A. Schmidt) near Sarnia, Ontario, was reported in 1941 by H. D. Brown, formerly chief agriculturist of the Canada and Dominion Sugar Company. This represented the first report of the pest in a sugar beet growing district east of the Mississippi. According to Brown, the sugar beet nematode was first noted in 1931 as two small patches in one field. When sugar beets were planted in this field in 1940, nematode injury again developed in the areas previously noted as affected. Infestations in other fields in the immediate vicinity were found in 1939 and 1940.

During the summer of 1948, the writer received a request to examine a field of sugar beets near Bay City, Michigan, in which the sugar beet nematode was thought to be present. Examination of the roots of wilted plants revealed the presence of large numbers of nematode cysts. Samples of the soil and of the sugar beet plants were sent to the Division of Nematology, Beltsville, Maryland, and the field determination was confirmed by Dr. G. Steiner. About three acres of the field, as evidenced by wilting and unthrifty appearance of the sugar beet plants, appeared to be infested seriously. The farmer in whose field the sugar beet nematode was found stated that he had observed poor growth of sugar beets in the affected area as early as 1942. His practice for this field was to alternate the sugar beet crop with potatoes.

Another field of sugar beets near Mount Clemens, Michigan, was examined on September 13, 1948. Sugar beet nematodes were present on the roots of wilted plants. The size of the infested areas and the injury to plants were less than in the Bay City field.

In 1949, Perc A. Reeve and Grant Nichol of the Farmers & Manufacturers Beet Sugar Association collected samples of sugar beets from four fields near Indiantown, northeast of Saginaw, Michigan. The sugar beet nematode was found on the roots and had caused dwarfing and wilting. The infested fields had been planted to sugar beets every two or three years for a considerable period. Decreased yields from affected areas for at least six or seven years had been noted by the sugar beet growers. The finding of the sugar beet nematode as a serious infestation in a few fields in sugar beet growing districts of Michigan indicates the need of surveys to determine the situation in eastern sugar beet districts.

Certain steps have already been taken to prevent spread. The practice in Ontario has been to retire certain fields from sugar beet cultivation and longer rotations have been proposed for others. Certain sanitary practices in handling sugar beets from fields found to be infested have been considered. The Farmers and Manufacturers Beet Sugar Association, in coopera-

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tion with the Dow Chemical Company, has applied chemical treatments to infested areas near Saginaw. It is recognized that such treatments merely reduce the number of nematodes and have not served to eradicate the pest. Longer crop rotations than those in common use may now be required by beet sugar companies, not alone to prevent the spread of this new pest but as an improved farm practice. In this policy they are being guided by the experience of sugar beet growers in western United States where effective nematode control has been obtained through use of long rotations, as long as weeds which harbor the nematode have not been present to defeat the very purpose of the rotation. The recent development of new nematacides may assist in the control of the sugar beet nematodes. Far more important is the opportunity that now seems offered to the industry to confine the infestation essentially to its present rather limited distribution.

Summary

Sugar beet nematodes were found in 1948 near Bay City and Mount Clemens, Michigan, and in 1949 in four fields near Saginaw, Michigan. The infested fields were in short rotations in which beets occurred every other year or every third year.

Longer rotations, sanitary practices in handling beets from infested fields, and chemical treatments of infested areas are recommended to confine the nematode to its present limited distribution in Michigan.

Lygus Damage to Sugar Beet Seed In Various Stages of Development[1]

ORIN A. HILLS AND EDGAR A. TAYLOR[2]

Field-cage studies previous to 1945 (Hills *1*, *2*)[3] showed that the feeding of lygus bugs (*Lygus oblineatus* (Say), *L. hesperus* Knight, and *L. elisus* Van Duzee) was one factor responsible for the reduction in the viability of sugar-beet seed[4]. In that work the insects were encaged on sugar-beet plants about the time the first flowers opened and were allowed to remain until the seed matured. There was therefore no evidence of the stage of development of beet seed, between flower bud and seed maturity, during which lygus bug damage occurred. From 1945 to 1948, inclusive, experiments were conducted in field cages to determine at what stage of development beet seed was most susceptible to lygus bug injury. The purpose of this report is to present the results of a series of experiments begun in 1945, some of the preliminary results of which were discussed at a previous meeting of this Society in 1948.

Methods and Materials

The seed beets used in these experiments were of the curly-top-resistant variety known as U. S. 22. The cages used in 1945, 1946 and 1947 were cylindrical, 30 inches in diameter, 5 feet tall, and covered with open-mesh curtain scrim. Each cage enclosed the entire inflorescence of one sugar-beet plant. A group of these cages, in place on the plants, is shown in Figure 1.

In 1945 and 1946 75 cages were arranged in randomized block of 5 treatments and 15 replicates. Plants in four stages of seed development, from prebloom to nearly mature seed, were exposed to lygus infestations for 2 weeks. The first introductions were made into the cages when the plants reached the flower-bud stage; subsequent introductions were made at 2-week intervals. The fifth cage in each block was maintained insect-free as a check. Into each cage were placed 100 lygus bugs, a mixture of *L. hesperus* and *L. oblineatus*, gathered either from alfalfa or town mustard. At the end of the exposure period they were killed with DDT dust.

In 1947 72 cages were arranged in the field as randomized blocks of 6 treatments and 12 replicates. As in 1945 and 1946, 100 lygus bugs were introduced into cages containing plants in different stages of development. However, in 1945 and 1946 lygus were introduced into all cages of a given treatment on the same date, the date being selected when most of the plants in the series were in the desired stage of development. In 1947 lygus bugs

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[1] Presented at the meeting of the American Society of Sugar Beet Technologists at Detroit, Mich., February 6-9, 1950.

[2] Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, U. S. Department of Agriculture. The Beet Sugar Development Foundation furnished a temporary assistant during the summers of 1946 to 1948. The University of Arizona cooperated in planting and maintaining the beet plots on which the experiments were conducted in 1947 and 1948.

[3] Numbers in parentheses refer to literature cited.

[4] Sugar-beet seed in commercial usage refers to seed balls, each of which may contain one or more true seeds. In this paper the common practice of referring to the seed balls collectively as "seed" is followed.

were introduced into each cage when the plant within that particular cage had reached the specified stage of development. The insects were then allowed to remain within the cage only 1 week instead of 2 weeks as in 1945 and 1946. As beet seed develop progressively on a plant (blooming beginning at the bases of the spikelets and proceeding toward the tips), there is never a time when all immature seed are in the same stage of development. The aim of the 1947 experiments was to confine the lygus infestations as closely as possible to the following development stages of the seed:

Figure 1. Field cages for determination of lygus damage to beet seed in varying stages of development. 1945 to 1947.

Prebud—Seed stalk mostly vegetative but flower buds beginning to develop.

Flower bud—Side branches developing on the seed spike and flower buds in evidence.

Early bloom—Side branches well developed on seed spike with open flowers at base of spikelets.

Full bloom—Maximum possible number of open flowers.

Early seed—Newly formed seed in central portion of spikelet with mature, hard seed toward base and a few open flowers toward the tip.

The sixth cage in each block was maintained insect-free as a check. Most of the lygus bugs used in this experiment were taken from alfalfa and were predominantly *L. hesperus* with a few *L. oblineatus*.

The experiments in 1948 differed from those in previous years in that all cages within a block were placed on a single seed-beet plant. This was

done in an effort to reduce the experimental error due to the normal variation between plants, and made necessary some changes in equipment, methods and arrangement of the experiment. During the winter months the seed beets to be used for this experiment were thinned to 1 foot apart, and as soon as bolting occurred in the spring the central stalk of each plant was removed to encourage the production of several seed stalks.

The cages used in 1948 were only 1 foot in diameter and 3 feet long. Each cage was suspended from a wooden frame as shown in Figure 2. One

Figure 2. One block of field cages in place on multiple-bolting seed beet. 1948.

hundred cages were arranged in the field as randomized blocks of 4 treatments and 25 replicates. The technique employed in 1948 reduced the quantity of seed per cage; therefore only 25 lygus bugs were used in a cage instead of 100. The insects were allowed to remain on the seedstalks for 1 week. On each plant one encaged seed-stalk was infested in the flower-bud stage of development, one in the full-bloom stage, and one in the soft-seed stage (Figure 3). The fourth was maintained insect-free as a check. The lygus

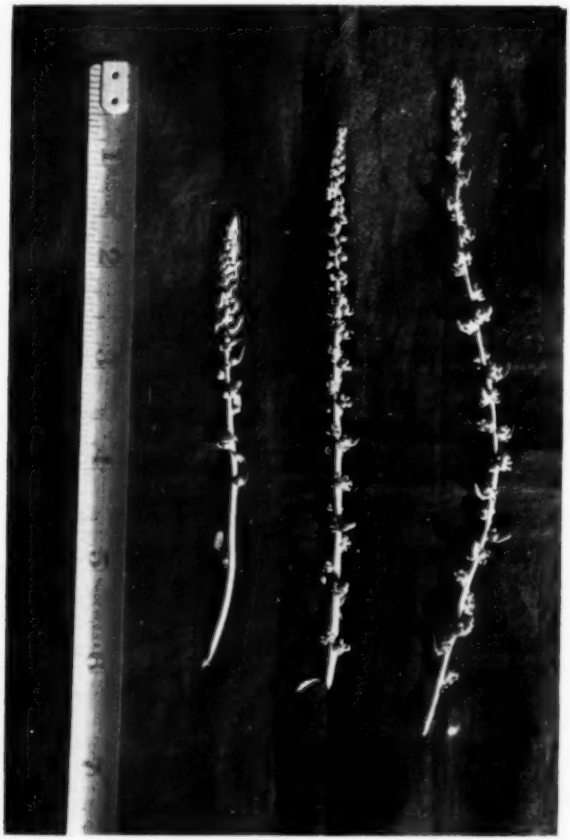

Figure 3. Seed-beet spikelets representing different stages of seed development during lygus infestations of 1948. From left to right these developmental stages were indicated as flower bud, full bloom, and soft seed.

bugs were obtained from alfalfa, as in 1947, and consisted largely of *L. hesperus* with an occasional *L. oblineatus*. They were introduced into each cage when the maximum number of seed therein was in the desired stage of development.

At maturity the seed from each cage was harvested, hand-threshed, and cleaned through a miniature mill over a 7/64-inch screen. Seed balls smaller than 7/64 inch in diameter were discarded. Yield was determined by weighing the cleaned seed, and viability was determined by germinating a sample of 400 seed balls from each cage. The germination tests included sprout counts to determine the percent of viable seed balls and the number of sprouts per viable ball.

Results and Discussion

Weather conditions in 1945 and 1946 were such that seed development in 1946 was more rapid than in 1945, as indicated in the first two columns of Table 1. These differences in plant development are reflected in the results of the experiment. In 1946 considerable soft seed was formed during the first exposure period and under these conditions seed viability and seed yield were reduced significantly. In 1945 seed development was slower, fewer soft seed formed during the first exposure period, and there were no significant reductions in seed viability or yield until the second exposure period. There were fewer sprouts per seed ball owing to lygus feeding during the first two exposure periods of both 1945 and 1946.

Table 1.—Viability and yield of sugar-beet seed on plants exposed at different stages of seed development to lygus infestation in field cages. Phoenix, Ariz., 1945 and 1946.

Seed development		Yield of seed per cage		Viable seed balls		Sprouts per viable seed ball	
1945	1946	1945 Grams	1946 Grams	1945 Percent	1946 Percent	1945 Number	1946 Number
Flower bud to full bloom	Flower bud to late bloom	87	39	74	42	1.36	1.21
Full bloom to late bloom and early seed	Late bloom to early seed	60	51	16	19	1.39	1.36
Late bloom and early seed to soft seed and maturing seed	Early seed to soft seed and maturing seed	90	67	47	64	1.55	1.63
Soft dough and maturing seed to late, hard, mature seed	Mostly mature seed	82	64	74	84	1.61	1.55
Insect-free cages (check)	Insect-free cages (check)	118	64	78	96	1.57	1.64
Difference required for significance ($P = 0.05$)		30	20	12	12	0.15	0.15

Results of the 1947 and 1948 experiments are summarized in Tables 2 and 3. These data show significant reductions both years for the percent of viable seed produced during the full-bloom and soft-seed stages of development. Although the maximum number of soft seed occurred in the cages during the full-bloom period. The reduction in the percent of viable

seed balls during these two periods for both years is approximately proportional to the number of soft seed present at the time of exposure to lygus. In 1948 there were significant reductions in the number of sprouts per ball during the full-bloom period. It is possible that lygus may have damaged individual flowers during the blooming period before the ovaries fused to form the seed ball. In 1947 and 1948 infestations before the full-bloom period did not produce a measurable effect on the developing beet seed. No significant reductions in seed yield are indicated for either 1947 or 1948.

Table 2.—Viability and yield of sugar-beet seed on plants exposed at different stages of development to lygus infestation in field cages. Phoenix, Ariz., 1947.

Seed development	Yield of seed per cage Grams	Viable seed balls Percent	Sprouts per viable seed ball Number
Prebud	80	98	1.80
Flower bud	83	98	1.86
Early bloom	89	96	1.71
Full bloom	87	87	1.68
Soft seed	104	66	1.61
Insect-free cages (check)	99	99	1.74
Difference required for significance ($P = 0.05$)	[1]	8	[1]

[1] Not significant by the F test.

Table 3.—Viability and yield of sugar-beet seed from seed stalks of the same plant exposed at different stages of seed development to lygus infestation in field cages. Tempe, Ariz., 1948.

Seed development	Yield of seed per cage Grams	Viable seed balls Percent	Sprouts per viable seed ball Number
Flower bud	42	94	1.48
Full bloom	41	89	1.43
Soft seed	40	83	1.50
Insect-free cages (check)	45	93	1.52
Difference required for significance ($P = 0.05$)	[1]	3	0.05

[1] Not significant by the F test.

Summary and Conclusions

In Arizona, from 1945 to 1948, experiments were conducted in field cages to determine the effect of lygus infestations on sugar-beet seed in different stages of development. The results of these experiments indicate that the primary damage of lygus to sugar-beet seed is the reduction in the percent of viable seed. These losses were also accompanied by a reduction in the number of sprouts per viable seed ball. Reductions in yield were indicated where lygus infestations were sufficiently severe, as in 1945 and 1946 when infestations consisted of 100 lygus per plant over a period of 2 weeks.

Results of these experiments further indicate that the greatest amount of damage is to the soft and newly formed seed. This is more clear-cut in the experiments of 1947 and 1948 than in the earlier experiments, since in 1947 and 1948 the infestations were of only 1 week's duration and also the introductions during the last 2 years were made to the plants individually in the desired stage of development. Results of the 1947 experiments showed that there was no damage in the prebud, flower-bud, or early bloom stages of development. There was some damage in 1947 and 1948 from lygus infestations on plants in the full-bloom stage, but the maximum damage occurred from infestations in the late-bloom to early seed stage of development. Some soft seed occurred in those cages in which infestations were made during the period designated as full bloom, but greater damage occurred during the infestation period designated as soft seed. It is therefore probable that the damage in the preceding infestation period was largely to the soft seed present on the plants at that time.

In 1945 and 1946, when infestation periods were of 2 weeks' duration and infestations were made on the same date to all plants within a treatment, the results are not so clearcut as in 1947 and 1948. However, when one considers the overlapping of plant development and the fact that the damage was greatest within the cages containing the largest number of soft seed during the infestation period, the data corroborate those of 1947 and 1948 and indicate again that the greatest amount of damage from lygus may be attributed to infestations in the early seed stage of development. In both 1945 and 1946 the last infestations were made to plants in later stages of seed development than in 1947 and 1948. These infestations to mature or nearly mature seed caused little or no damage. Likewise, infestations in 1947 and 1948 to plants before the blooming period resulted in no damage.

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1943. Comparative ability of several species of *Lygus* and the Say stink bug to damage sugar beets grown for seed. Jour. Agr. Rs. 67 (10): 389-94.

Effect of the Say Stink Bug On Maturing Sugar Beet Seed

ORIN A. HILLS AND EDGAR A. TAYLOR[1]

The Say stink bug, *Chlorochroa sayi* Stal., is erratic in its occurrence in sugar beets grown for seed. However, all the southwestern area in which the crop is grown is subject to outbreaks of this insect. In some years the insects move into the seed-beet fields in large numbers as the crop is approaching maturity. They have been known to remain in the shocks and windrows for an appreciable time after the cutting. Previous work (Hills 1941 and 1943; Hills and McKinney 1946) had shown that the viability of the seed was greatly reduced where adults and nymphs of the Say stink bug were allowed access to developing beet seed, from the bloom stage to maturity, but the effect of these insects on mature or nearly mature beet seed was not known. Therefore, during the spring of 1948, a field-cage experiment

Figure 1. One block of cages in place on a multiple-bolting seed beet.

[1] U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine.

was conducted to determine the effect of infestations of the Say stink bug on maturing sugar-beet seed.

Methods and Materials

Seed beets grown in cooperation with the University of Arizona near Tempe, Ariz., were used for these studies. Previous to the cage tests the beets were thinned to 1-foot intervals, and as soon as the plants bolted the central seed stalks were removed to cause the production of multiple seed stalks. The cages were cylindrical, 1 foot in diameter and 3 feet long. They consisted of a wire frame covered with curtain scrim (22 threads per inch). Each cage enclosed the entire inflorescence of 1 seed stalk. Twenty-one cages were arranged in 7 randomized blocks. Each block consisted of 3 cages placed on separate stalks of the same plant (Figure 1). This precaution

Table 1.—Viability and yield of sugar beet seed produced in field cages infested with Say stink bugs for 2 weeks before and 2 weeks after the stalks were cut.

Period insects were on plants	Average yield per cage	Average germination	Average sprouts per viable ball
	Grams	Percent	Number
Before cutting	112	28	1.22
After cutting	90	80	1.94
None (check)	146	91	2.26
Difference required for significance ($P = 0.05$)	[1]	14	0.29

[1] Not significant by the *F* test.

was taken to reduce variation within blocks. In one cage of each block, 25 adults of the Say stink bug were introduced 2 weeks before the plants were to be cut for harvest and allowed to remain until cutting time, when they were killed with a benzene hexachloride dust. In another cage the same number of adults was introduced immediately after the cutting and allowed to remain for 2 weeks. The third cage was kept insect-free as a check. All the stalks were cut at the same time and kept in windrows with the cages intact. The cages were removed from the windrows 2 weeks after the cutting; the seed from each cage was threshed, cleaned and weighed to determine yield, the samples were taken for germination tests. Germination analyses consisted of sprout counts to determine the average number of viable seeds per viable ball as well as the percent of viable seed balls.

Results and Conclusions

The results of this experiment are summarized in table 1. The grams of seed per cage were within the limits of experimental error. Adult Say stink bugs feeding for 2 weeks before the plants were cut caused a drastic reduction in the percent of viable seed balls and in the average number of seeds per ball. The adults feeding on the plants for 2 weeks after the cutting reduced the average number of seeds per seed ball.

These results indicate that adults of the Say stink bug can cause severe damage by feeding on sugar-beet seeds which are mature or nearly mature and may damage the seed in the windrow after the stalks are cut.

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Flea Beetle Control[1] In the Montana District

FORD T. SCALLEY AND ROWLAND M. CANNON[2]

The potato flea beetle *(Epitrix cucumeris)*[3] has, for the past two years, caused severe damage in the beet fields in the Milk River valley of Montana. During the spring of 1948 and again in the spring of 1949 high populations of flea beetles were noted throughout the district. It was not unusual to observe as many as from five to six flea beetles per seedling in many of the fields.

In 1948, in excess of 3,000 acres was replanted or abandoned. Stands were reduced severely in many cases and a major part of the entire acreage was damaged to the point that thinning was retarded two to three weeks. Late in the spring, a small acreage was dusted with a 5% DDT dust as recommended in 1946[4]. It was observed that the 5% DDT dust gave good control on the potato flea beetles and likewise eliminated banded flea beetles, three-spotted flea beetles and lygus bugs which were also noted in the fields prior to dusting. After dusting had been completed for 8 hours, we were unable to find actively feeding flea beetles. With this experience in hand, we laid plans to go into commercial dusting of flea beetles the following year.

In the spring of 1949, our early plantings emerged and seemed well on their way to an early thinning. It was possible to see down the rows in many of the fields throughout the district. Then, beginning about May 5, our fieldmen began to report that the flea beetles were causing some damage. Before we could get sufficient dusting equipment into the fields, many of the stands had been severely damaged. Fields which had been scheduled for thinning in two weeks were, in many cases, found to be practically barren.

Four ground dusters were put to work but it soon became apparent they could not hope to get over the acreage in time to maintain proper control. On the 19th of May, arrangements were made to use an airplane in conjunction with the ground dusters, and on the 26th of May a second plane was put into dusting service.

The first dusting was done on severely damaged fields in an attempt to prevent total destruction with subsequent replanting. In such cases, the beets varied in size from the cotyledon stage to six true leaves. After damaged fields had been dusted, an attempt was made to dust all fields just as the beets were emerging. This was an attempt to stop the damage before it had begun and also to reduce the damage done by the flea beetles before the beets had actually emerged through the top soil.

The soils in the Milk River valley are generally of a heavy type, and each spring there is considerable crusting. Careful examination throughout

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[1] The results reported in this paper are not the results of closely controlled experiments, but observations on a large scale commercial project.

[2] Utah-Idaho Sugar Co.

[3] "Insects and Diseases of the Sugar Beet"—Asa C. Mazson: "Recent taxonomic studies by L. G. Gentner indicate that what is now called *Epitrix cucumeris* in the western states is not the same as the eastern form and therefore should be given a different name."

[4] For a number of years, heavy potato flea beetle damage has been experienced in the Gunnison factory district of the Utah-Idaho Sugar Company in Utah. In 1946, at the request of the Utah-Idaho Sugar Co., Walter Peay and Howard Dorst of the Bureau of Entomology and Plant Quarantine, U. S. Dept. of Agriculture, tried several of the commercial insecticides in an attempt to determine a recommended control measure for potato flea beetles. They demonstrated that the 5% DDT dust would give effective control.

the spring pointed to flea beetle damage while the seedlings were still under crust. Many cases have been reported where the beetles were observed feeding from ¾" to 1" below the soil surface in the cracks and under the crust. Much of this damage we had previously erroneously associated with damping-off or from the work of insect larvae living in the ground.

Table 1.—Comparisons Regarding Acreage Dusted for Flea Beetles

Chinook District	Percent Replanted	Percent Abandoned	1949 Season Average Yield
Acreage Dusted	3.8	2.5	11.26
Acreage not Dusted	11.0	17.7	9.10

The planes used were Piper Cubs fitted with a hopper which held approximately 200 pounds of dust. The dust was fed through an adjustable slide gate in the hopper by a winddriven agitator and distributed from a homemade baffled Venturi tube fashioned by the owner of the plane. The Venturi tube was designed to provide coverage about 50' wide and strips were laid down on 33' centers to provide overlapping coverage. Refueling of the plane and refilling the dust hopper were accomplished in pastures or vacant fields adjacent to the beet area being dusted. Approximately 500 acres were dusted in one day by one of the planes.

Airplane equipment proved to be far superior to ground equipment in general. Some of the outstanding advantages noted are as follows: Mobility of the dusting units; ability to dust fields too wet to accommodate ground equipment; greater dusting capacity per unit; better penetration of dust into surface mulch and cracks; and less delay due to mechanical difficulties. Our experience indicated that airplane dusting costs with a well-planned operation appear to be very comparable with ground dusting costs.

A 5% DDT dust at the rate of 12 pounds per acre gave satisfactory control on all acreage where dusting conditions were favorable. During the peak of the dusting period we received precipitation totaling 3½" of moisture. In many cases, rain fell on fields within a few hours after they had been dusted. No appreciable difference was noted in control in such cases. Ground dusters were able to work under almost all conditions and gave good control. The planes, however, did have to re-dust two fields which were dusted originally under unfavorable conditions.

A limited acreage was sprayed with high-pressure ground sprayers using approximately 1-1½ pounds of technical grade DDT in 50 gallons of water applied to an acre. The spraying did not demonstrate as effective control as did the dusting.

The fields which were dusted which had been severely damaged and in which high populations of flea beetles were working recovered quickly after dusting. Where dusting was done prior to damage by flea beetles as a protective measure, the flea beetle populations were noted to be at a minimum throughout the thinning period. Observations indicated that nearly 100% kill was realized within 24 hours after dusting. Very often flea beetles would again appear in small numbers within a week or ten days. We observed no cases, however, where populations after dusting caused severe damage.

After considerable observation with the results of dusting, it is felt that many fields could be dusted to advantage which have in the past not been considered to have suffered too much damage.

The statement has been made in the Milk River valley that, regardless of when the beets emerge, thinning will not begin until approximately June 1. It is felt by the authors that this flea beetle damage very possibly has been responsible to a major degree for this situation.

The results of the past year's commercial dusting operation are best exemplified in Tables 1 and 2.

In Table 1 it is noted that the percent of acreage replanted was almost three times as great where the acreage was not dusted as where dusting was accomplished. On the acreage dusted, only 2.5% was abandoned as against 17.7% abandoned on the acreage not dusted. The dusted acreage showed an average yield of 2.16 tons per acre more than the average yield of the acreage not dusted.

Table 2.—Comparison of yield trends between contracts where beets were dusted and were not dusted for flea beetles.

Chinook District					1949 Season	
	Tonnage in better class than the average of the past 5 years		Tonnage in same class than the average of the past 5 years		Tonnage in poorer class than the average of the past 5 years	
	Acreage	% of Acreage	Acreage	% of Acreage	Acreage	% of Acreage
Dusted	1101.26	25	1819.19	41	1476.76	34
Not Dusted	409.00	11	1109.04	29	2319.60	60
Total	1510.26	18	2928.23	36	3796.36	46

Note: Tonnage brackets used were:
(a) Over 13 tons per acre
(b) 11 to 13 tons per acre
(c) 9 to 11 tons per acre
(d) 7 to 9 tons per acre
(e) 5 to 7 tons per acre
(f) Below 5 tons per acre
Yields used were average yields for the contract.

In Table 2 a comparison is made of yield trends between contracts where beets were dusted and where beets were not dusted for flea beetles. It is of interest to note that, of the dusted acreage, 25% was in a better class than the average of the past five years as against 11% for the acreage not dusted. Forty-one percent of the acreage which was dusted was in the same tonnage class as the average of the past five years as against 29% of the acreage not dusted, and only 34% of the acreage which was dusted fell in a poorer class than the average of the past five years as compared with 60% of the acreage which was not dusted. Yield results would possibly have been more marked had we not suffered a severe killing frost on the 12th of September which stopped growth on all beets.

An interesting example of the value of dusting can be cited in the case of eight farms in Valley county which were dusted during the second week of May. On May 28, while arranging for plane dusting in Valley county, a survey was made of the fields in that area. Beets were being thinned on all eight farms which had been dusted two or three weeks earlier. These were the only farms in Valley county which were being thinned.

After the experience of the past year, we are advising all beet growers throughout the entire district to dust every acre of beets at the time they are emerging through the ground. Prectically all farmers whose acreage was dusted last spring are demanding that dusting facilities be available for the coming year.

Survival of the Beet Leafhopper in Southern Idaho During the Severe Winter of 1948-49

J. R. DOUGLASS, V. E. ROMNEY, AND H. C. HALLOCK[1]

The beet leafhopper (*Circulifer tenellus* (Bak.)) overwinters in the adult stage. Females are fertilized in the fall and live until spring. The males die during the winter. The effect of subzero temperature on winter survival of the insect needs to be better understood. Snow cover gives excellent protection to the soil surface from subzero temperatures. Carter (1)[2] showed from thermograph charts "that when snow fell prior to cold waves the temperatures at the surface of the soil were practically constant at around freezing point during the succeeding cold weather when air temperatures fell considerably below zero."

Hills (3), studying the fall and winter survival of the beet leafhopper at Hermiston, Oregon, reported that during the month of January, 1930, there were 16 days of subzero air-temperature with a minimum of —38° F. During this period there were 15 inches of snow on the ground. These conditions had little, if any, effect on the insect. During the winter of 1932-33 there were 7 days of subzero air temperatures, with a minimum of —9° in December. There was no snow cover during this period, and the soil-surface temperature dropped to 2°. On February 9 the minimum air temperature decreased to —5°, also without snow cover, and the soil-surface temperature dropped to 5°. These extremely low soil-surface temperatures did affect the survival of overwintered female leafhoppers, as only 4 percent survived.

Later studies in southern Idaho corroborated Hills' conclusion that snow cover enables the leafhopper to withstand subzero air temperatures. The effect of low temperatures on beet leafhopper survival obtained under controlled conditions, as reported by Harries and Douglass (2), showed that mortality evidently depends on the length of exposure, as well as on the degree of cold. Their data showed "complete mortality of groups of overwintering females in approximately 20 days of 30° F., 15 days at 20°, 11 days at 15°, 6 days at 10°, 2 days at 5°, less than 12 hours at 0°, and less than 5 hours at —4°. The average survival is roughly one-half these specified exposures. These results also seem to agree fairly well with those of Carter * * * who found that the overwintering famales rarely survived 4-hour exposures to —2° F., —10°, and —14° in a commercial refrigeration plant, or when chilled to 0° or lower in laboratory apparatus." They concluded from the above data that extended cold periods, when the ground is covered with snow or the soil-surface maximum temperatures do not rise above 32°

[1] U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine. In cooperation with the Bureau of Plant Industry, Soils, and Agricultural Engineering of the U. S. Department of Agriculture and the Idaho Agricultural Experiment Station.

[2] Numbers in parentheses refer to literature cited.

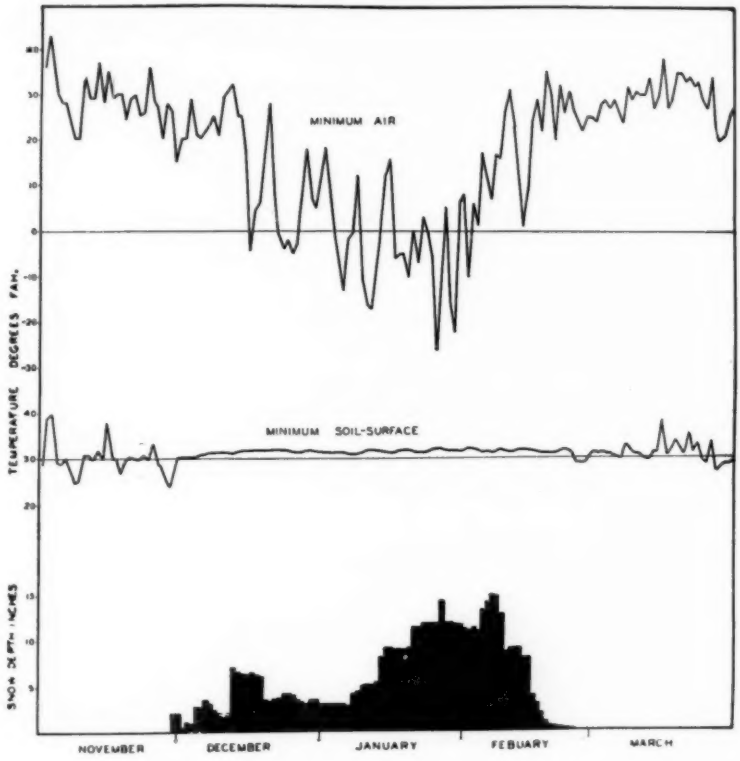

Figure 1. Minimum air and soil-surface temperatures, together with snow cover, at Twin Falls, Idaho, for the winter of 1948-49.

F. for 1 or 2 weeks or more to permit feeding or absorption of moisture, would seem to be very unfavorable for survival.

From this information it was expected that a very low survival of leafhoppers would follow the winter of 1948-49. Evidently, controlled-temperature studies are not dependable criteria for actual field conditions. It is probable that temperatures above the freezing point of the insect and up to 30° F. for any length of time would cause desiccation. Apparently, beneath snow, where the temperature was 31°-32° F., desiccation is very limited.

Studies of leafhopper survival under natural and cage conditions during the winter of 1948-49 in southwestern Idaho showed that this insect survived fairly well beneath a continuous snow cover ranging from 2 to 15 inches

for a period of 88 days, between November 30, 1948, and February 25, 1949. The winter was the coldest on record for southwestern Idaho. There were 24 nights of subzero weather at Twin Falls, Idaho, 17 of which were in January with a minimum of —26° F. Soil-surface thermographs showed that the temperature beneath the snow was from 31° to 32° F. Figure 1 shows the minimum air and soil-surface temperatures, together with snow cover. Figure 2 shows thermograph charts for air and soil-surface temperatures for the

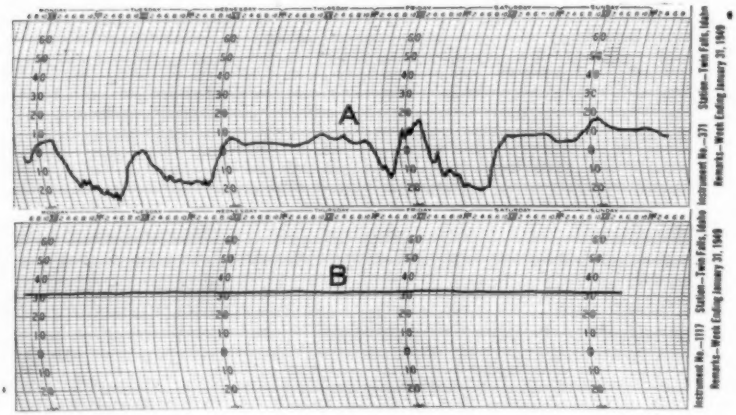

Figure 2. Thermograph records of air temperatures (A) and soil-surface temperatures under snow (B) for the week ending January 31, 1949, at Twin Falls, Idaho.

week ending January 31, 1949, during which period the coldest weather occurred.

Surveys in September, 1948, showed a comparatively low fall population of beet leafhoppers on Russian-thistle *(Salsola kali* var. *tenuifolia Tausch).* These leafhoppers entered the winter of 1948-49 under adverse host-plant conditions. Spring surveys in 1949 showed a moderate population of beet leafhoppers which had overwintered. This survey also showed widespread and abundant germination of its spring and summer host plants over most of southwestern Idaho. The spring of 1949 was warm and dry, very favorable conditions for the development of the spring generation of beet leafhoppers. The spring movement into beetfields on the west end of the Twin Falls irrigation tract averaged 626 adult leafhoppers per 100 square feet, as compared with a 15-year average of 805, even though about 2,600 acres of the more productive spring breeding areas were sprayed for the control of the spring migrants.

The beet leafhopper is known to have overwintered in some areas which have a colder climate than Twin Falls, Idaho, such as Billings, Montana, and the Big Horn Basin, Wyoming. No doubt snow cover was important in protecting them during subzero weather. Mean temperatures at stations

in these areas as well as at Kalispell, Montana, and Ephata, Washington, are illustrated in Figure 3. The mean normal temperature for the coldest of these areas was as much as 12° below that at Twin Falls, Idaho, and yet beet leafhoppers have survived several winters in these areas.

A review was made of the data on beet leafhopper survival during four other cold winters in southern Idaho, and it was found that the low temperatures did not reduce materially the overwintering population. The winters

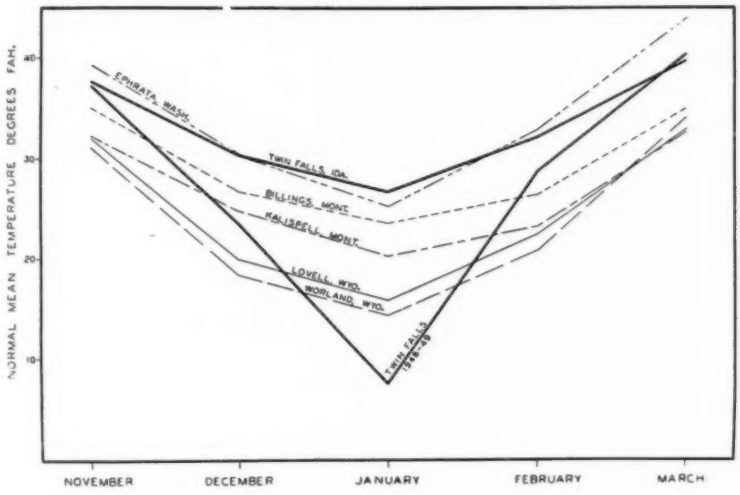

Figure 3. Mean monthly temperatures at Twin Falls, Idaho, for the winter of 1948-49 compared with the normal mean monthly temperatures for Twin Falls, Idaho; Billings and Kalispell, Montana; Lovell and Worland, Wyoming; and Ephata, Washington.

of 1928-29, 1931-32, 1932-33, 1936-37, and 1948-49 were outstandingly cold. The populations entering the first three winters were low, and the spring generation of beet leafhoppers following these winters was light. The 1936 fall population of beet leafhoppers was high and damage was severe in the spring of 1937. Subzero temperatures without snow cover are unfavorable to survival, and such conditions are more likely to occur during moderately cold winters than during the coldest of winters, since snow generally precedes subzero weather in southern Idaho. In general, cold winters do not seem to be unfavorable to the survival of the beet leafhopper because of the protection by snow cover.

Summary

The winter of 1948-49 was the most severe on record for southwestern Idaho. The temperature was subzero on 24 days during the winter, 17 of which were in January, with a low of —26° F. Snow covered the ground

continuously from November 30, 1948, to February 25, 1949, in southcentral Idaho. Soil-surface temperatures beneath the snow were from 31° to 32° F. Surveys in September, 1948, showed a comparatively low fall population of the beet leafhopper (*Circulifer tenellus* (Bak.)) on Russian-thistle. These leafhoppers entered the winter under adverse host-plant conditions. Spring surveys in 1949 showed a moderate population of overwintered beet leafhoppers, indicating that this insect survived fairly well beneath a continuous snow cover for a period of 88 days. A review of the data from four other cold winters also indicated a fairly good survival. During severe winters there is usually a snow cover adequate to protect beet leafhoppers from subzero temperatures.

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Plant Pathology

Savoy, a Virus Disease of Beet Transmitted by Piesma Cinerea

G. H. COONS, JOHN E. KOTILA AND DEWEY STEWART[1]

The sugar beet disease known as "Savoy" was first described in 1892 in Indiana by Arthur and Golden (1)[2], and was considered by them to be caused by a bacterium. Some years later, Cunningham (3), working under the direction of Arthur, again attributed the disease to a bacterial organism but without convincing evidence of pathogenicity. Towar (5) in 1901 described and illustrated "leaf curl" of sugar beets as occurring in Michigan.

The photographs and descriptions leave little doubt that these are early records of sugar beet Savoy. The writers (2) reported in 1937 that the disease is caused by a virus, named it "Savoy," and stated that a species of lace bug, *Piesma cinerea* Say had been proved to be the insect vector of the virus.

Plants affected by savoy (sugar beet, red garden beet) show dwarfed, down-curled, savoyed leaves (Figure 1). The most pronounced effects are found on the innermost leaves. Primary symptoms of the disease are veinlet clearing, followed by thickening of the veinlets, giving the dorsal surface of a leaf a netted appearance. Roots of affected plants show in late stages phloem necrosis and flesh discoloration, simulating curly top effects. After an initial partial involvement of leaves and root, the disease becomes general. Roots of diseased plants test low in sucrose.

Only adults of *P. cinerea* have transmitted the virus. Both viruliferous and non-viruliferous individuals have been found. The virus overwinters in affected plants and probably in the vector. The incubation period in sugar beets is 3 to 4 weeks. Graft transfers have been successful, but the cion from a diseased plant must be left in place at least 7 days for the virus to be transmitted. This is taken to indicate that the virus affects chiefly the phloem of the beet. Attempts to transmit the virus by means of juice, aphids (*Myzus persicae* Sulz., *Aphis rumicis L.*), leafhoppers, including the beet leafhopper (*Circulifer tenellus* (Baker)), or by dodder, have been unsuccessful. The disease has been found in Maryland, Michigan, Ohio, Minnesota, Nebraska, South Dakota, Colorado, Texas and Montana. In sugar beet fields the incidence has ranged from a trace to about 5 percent. In portions of fields near a woodlot or waste land, the disease incidence may be far higher than the field averages. The disease has been reported from Ontario (4).

Savoy appears most closely related to Krauselkrankheit of sugar beets and related plants in Central Europe. The vector of the European virus is *Piesma quadrata* Fieb. These diseases differ distinctly from curly top.

So far, sugar beet savoy has been relatively minor in its effects upon crop production in the United States.

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[2] Numbers in parentheses refer to literature cited.

Figure 1. Savoy of Sugar Beets. One-sided involvement of the plant following mid-season attack is shown. Older leaves are stunted and crinkled. Their veinlets are thickened; lower surfaces of affected leaves have netted appearance. Younger leaves are curled and distorted; their veinlets commonly show clearing.

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Combination and Separation of Curly-Top Virus Strains

N. J. GIDDINGS[1]

Introduction

Most viruses are known to occur as strains which differ greatly in virulence. In many instances infection by one strain of a virus gives evidence of immunizing the host against other strains of the same virus as is so well known in the case of the animal disease, smallpox.

Carsner[2] reported that a sugar beet plant showing mild curly-top symptoms was inoculated with virus from a severely diseased plant and that it soon developed severe symptoms. No other experiments along that line have been reported for the curly-top virus *Ruga verrucosans* (Carsner and Bennett).

For the convenience of those not familiar with the different strains of curly-top virus, Table 1 gives the symptoms induced by strains 1, 2, 3 and 5, the four strains most involved in the experimental work here reported.

Table 1.—Comparative symptoms induced in young sugar beets by the four virus strains most used in this work.

Virus strain	Symptoms on Susceptible beet (S.L. 842)	Resistant beet (S.L. 68)
1	Extreme distortion, curling and dwarfing. Occasional death.	Pronounced vein clearing, usually some leaf curling. Slight dwarfing.
3	Extreme distortion, curling and dwarfing. Occasional death.	Infection very rare. Extremely slight vein clearing on any infected plant.
2	Either slight curling of leaves with pronounced vein clearing or numerous papillae, or both. No obvious dwarfing.	Slight or pronounced vein clearing. Occasional slight leaf curling. No dwarfing.
5	Very little distortion but extreme dwarfing and high mortality.	Slight vein clearing. Very rarely slight leaf rolling. Slight dwarfing.

Immunizing Effects of One Virus Strain Upon Another Strain

Curly-top virus strains 1 to 7 were each tested to learn whether any one of them would immunize a sugar beet plant against infection by one of the other strains in that group. It was found that plants infected by any of the less virulent strains could be infected readily by the more virulent strains and that plants first infected by the more virulent strains could again be infected using the less virulent strains. In the latter group, primary infection by the more virulent and secondary infection by the less virulent, the second virus strain does not induce any change of symptoms in the infected plant and it is necessary to determine the presence of the less virulent strain by transferring the suspected virus mixture to some differential host plant. There

[1] Senior Pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture.

[2] Carsner, Eubanks. Attenuation of the virus of sugar beet curly top. Phytopathology. 15: 745-757. (1925).

were 12 paired combinations of the virus strains in this group and in four cases I was able to prove the presence of the less virulent strains by means of differential hosts but no satisfactory method is known for proving the presence of the second virus in the other eight combinations. For example, a plant may be infected by virus strain 1 and then inoculated with strain 2 but no differential host has been discovered which will give evidence of the presence of strain 2 after inoculation with a mixture of strains 1 and 2. In other words, strain 1 always masks strain 2 on any of the hosts thus far tested.

There are 42 possible paired combinations among the seven strains and in no case did I find evidence that infection by one strain of virus immunized the sugar beet against infection by a second strain. There were 24 combinations for which we had satisfactory differential tests to prove the presence of the second virus and 18 combinations for which a satisfactory test is not yet known.

Does Infection by One Virus Strain Retard Subsequent Infection by Another Strain?

Some preliminary experiments have given evidence that infection of plants of the susceptible sugar beet variety S. L. 842 by the less virulent virus strain 2 did not retard subsequent infection of the same plant by the more virulent strains 1 or 3. In each of the three experiments it was also noticeable that the plants infected by the second virus showed more severe curly-top symptoms than similar plants infected by either of those strains alone, but more data should be obtained for determination of the statistical significance of these differences. Using the resistant beet variety U. S. 22 and the less virulent strains 2 or 7 for the first inoculation, it was found that subsequent infection by the more virulent strain 1 or selection 22 was not retarded. These experiments give further evidence that more than one virus strain may be involved in the infection of the same sugar beet plant.

Virus Strain Concentration as Influenced by the Presence of One or More than One Strain in the Host

It seemed reasonable to suspect that the plants inoculated only with strain 2 or strain 3 would show a higher concentration of that particular strain than would be found in the plants infected by a mixture of the two strains. In each of two experiments one group of plants was inoculated with a mixture of virus strains 2 and 3 while a similar group was inoculated with virus strain 2. In one of these experiments a third group was inoculated with strain 3. Tests were made about three weeks after inoculation and at intervals until two months after inoculation but no significant differences were found. There was a high degree of variation between plants and between tests and, in general, it appeared that the concentration of strain 2 virus was just as great in the plant infected with strains 2 and 3 as it was in the plants infected by strain 2 alone. The same sort of evidence was obtained in the case of strain 3. These results are not considered conclusive but are certainly surprising. They are suggestive of the possibility that the nutrients required for each of these two strains of curly-top virus are different.

Strain Combinations as a Possible Source of New Strains

Early in the work with virus strains it was thought possible that strain 1 was actually a combination of strains 2 and 3, or that it arose as a result of maintaining those two strains in combination in a susceptible beet. In the resistant variety S. L. 68 the virus strain 2 induces symptoms which are similar to but not as severe as those induced by strain 1, while strain 3 rarely infects and then induces only very mild symptoms. In the susceptible variety S. L. 842 strains 1 and 3 induce severe symptoms which are indistinguishable while strain 2 induces only quite mild symptoms. The combined strains, when tested on both susceptible and resistant beets, gave results that strongly suggested strain 1 but the severity of symptoms induced on the resistant beet was rarely equal to that induced by strain 1 and it was always easy to again isolate strain 2 and strain 3 from the mixture. No evidence of a new or different virus strain was obtained from any of the numerous strain mixtures used in the course of many experiments.

Dominance of One Strain over Another under Certain Conditions

Virus strains 2 and 3 were maintained together in the same host for periods up to approximately two years and were separated and identified readily at frequent intervals during that time. Strain 2 was "filtered" from the mixture by using it to inoculate Turkish tobacco and recovering only strain 3. Strain 3 was eliminated from the mixture by passng it through the highly resistant sugar beet S. L. 68 and recovering only strain 2. It seemed clear that these two strains could exist together in the same sugar beet for an indefinite length of time.

In testing pairs of virus strains to determine whether one would immunize against another there was, as reported more fully elsewhere[3], some evidence indicating that strain 3 did immunize susceptible sugar beet plants against infection by strain 1. Ten trials all gave negative results. Symptoms induced by strains 3 and 1 are indistinguishable from one another in the susceptible sugar beet but strain 1 readily infects plants of the variety S. L. 68 while strain 3 very rarely infects them, so it is quite easy to determine whether 1 is present in a suspected mixture of 3 and 1. Further tests on susceptible sugar beets gave an occasional strain 3-infected plant which also became infected by strain 1 and tests with beets which were somewhat resistant to curly top gave a much higher percent of positive results.

To learn more concerning the behavior of virus strains 1 and 3 in the susceptible sugar beet plants some beet leafhoppers *Circulifer tenellus* (Baker) were fed for several days on a plant infected with strain 1, several days upon a plant infected with strain 3 and were then caged on a large, healthy, susceptible sugar beet plant. Tests from these leafhoppers at that time showed an abundance of strain 1 virus present. Tests from the nymphs which developed on these plants still showed abundance of strain 1 virus but subsequent generations indicated a progressive decline in the amount of strain 1 virus until, in from three to ten months, the tests gave no evidence that strain 1 was present. The leafhoppers were then transferred to sugar

[3] Giddings, N. J. Some interrelations of virus strains in sugar beet curly top. Phytopathology 40: 377-388. 1950.

beet plants which were more resistant to virus strain 3 than to strain 1 and occasional tests from them over a period of several months did not show any recurrence of strain 1. It would appear that strain 1 had been eliminated somehow by the dominance of strain 3. I have occasionally had evidence that strain 3 was prevalent in certain sugar beet fields in the spring and the overwintering of diseased, susceptible beets in that area could very easily account for that. While strain 1 has a wider host range and is more likely to induce injury on resistant beets, a susceptible sugar beet plant infected by both strains will eventually show only the strain 3 virus.

Some Conditions which Result in a Decrease in the Relative Prevalence of the More Virulent Virus Strains

While virus strain 3 may become dominant in a susceptible sugar beet, as has been shown, attempts to carry that strain in the highly resistant beet variety S. L. 68 eventually result in the production of colonies of non-viruliferous leafhoppers. On the other hand, strain 1 and most of the other curly-top virus strains may be carried in that resistant host indefinitely.

When such hosts as *Plantago erecta* Morris and *Lepidium nitidum* Nutt. are infected by the more virulent virus strains the plants are severely injured, with extreme dwarfing and a high percentage of the plants dying. They thus become less favorable for the increase of leafhopper populations. This fact as well as the death or small size of many of the virus sources must result in an automatic decrease in the ratio of the more virulent virus strains to the less virulent strains. As was pointed out two years ago[4], these facts may well account for the frequent predominance of some of the less virulent strains in the early spring.

Experiments Involving Leafhoppers which had Ingested Two or Three Virus Strains

Virus strains 2, 3 and 5 were used in these experiments because it is quite easy to distinguish the symptoms induced by each of them on young, susceptible sugar beet plants. It is also relatively simple to isolate strain 2 or strain 3 from any suspected mixture of these two.

After ingesting the virus strains each leafhopper was transferred daily to a young, healthy, susceptible sugar beet plant and the plants were kept under observation for approximately a month to determine whether they were infected and the character of symptoms induced. In some cases test plants of the resistant variety S. L. 68 were also used.

In two experiments leafhoppers were reared on a plant infected with strain 2 virus, fed for a few hours on a plant infected with strain 3 and then tested. There were 38 leafhoppers used in the tests and they were transferred to a total of 2,761 plants, making an average of slightly less than 73 transfers for each leafhopper. Curly-top symptoms developed in 1,664 (61%) of the test plants. Considering the first one-fourth of the total number of transfers for each leafhopper, there were 367 (55%) of the plants infected and a similar study of the last one-fourth of the transfers for each leafhopper showed 382 (58%) of the plants infected. There is no significant

[4] Giddings, N. J. Some studies of curly-top virus in the field. Proc. Amer. Soc. Sugar Beet Tech. 1948: 531-538.

difference between the 55% and the 58% and it is clear that the leafhoppers were infecting as large a percent of the test plants during the latter portion of the experiment as they were during the early portion, but there was an evident difference in the severity of symptoms. Of the 367 plants infected among the first one-fourth of the transfers, 215 (59%) developed symptoms characteristic of strain 3; whereas such symptoms appeared in only 123 (32%) of the infected plants included in the last quarter of the transfers.

This difference is highly significant and proved that the supply of strain 3 virus was being exhausted from leafhoppers which had fed only six to sixteen hours on that virus source.

Among the 1,664 infected plants in these experiments, at least 31 (2%) developed strain 2 symptoms and retained them for two weeks or longer but then developed strain 3 symptoms. This indicates that strain 2 may be dominant in such an infected plant for a while but that, given some combination of factors favorable to its development, strain 3 may develop rapidly and mask the strain 2 symptoms. In order to check this possibility further, tests were made from 583 of the infected plants which had shown only typical strain 2 symptoms and the strain 3 virus was recovered from 95 (16%) of them. This seems ample evidence that virus strain 3, and probably other strains, may be present in a sugar beet for several weeks or months without inducing symptoms.

Leafhoppers were tested after they had been fed for six and a half hours on a plant infected with virus strain 2, five hours on a plant infected with strain 3 and five hours on a plant infected with strain 5. Some of the test plants developed symptoms characteristic of strain 2, some developed symptoms of strain 3, some developed symptoms of strain 5 and, in a few cases, the plants developed rather confusing symptoms which were evidently a combination of 3 and 5. Approximately two and one-half percent of the infected plants developed strain 3 symptoms after showing strain 2 symptoms for two weeks or longer. It is reasonably certain that few, if any, of the test plants were inoculated with only one strain of virus; but in practically every case the visible symptoms were characteristic of one of the three virus strains. Either strain 3 or strain 5 would always mask strain 2 because their symptoms were more severe. Tests from 165 plants showing typical symptoms of strain 2, strain 3 or strain 5 proved that 69 (42%) of them contained one or both of the other virus strains. This would not prove that only one virus strain was present in the other 58% of the infected plants but would indicate that neither of the other strains was present in sufficient quantity to induce symptoms in the test plants during the period that they were under observation.

In this group of experiments there was no evidence of any change in the nature of the virus strains used and no indication of the development of any new strain.

Discussion and Summary

In a number of virus diseases it has been reported that infection by one strain of the virus will immunize the host against infection by another strain of the same virus but no evidence of any such immunizing effect in

sugar beet has been obtained in the case of curly-top virus. In plants of the susceptible sugar beet variety S. L. 842 the curly-top virus strain 3 will gradually become dominant over strain 1 when the inoculation has been made with a mixture of the two strains and will eventually eliminate strain 1 from that host. This, added to the fact that it is quite difficult to infect a susceptible plant with strain 1 after it has been infected by strain 3, suggests that there is competition and that perhaps strain 3 is more efficient than srain 1 in obtaining the available nutrients. Resistant sugar beets, such as U. S. 22, which are infected with strain 3 are rather easily infected by strain 1 and this would suggest that strain 1 may be able to utilize nutrient material which strain 3 is unable to utilize or that strain 1 may be less sensitive than strain 3 to some inhibitory substance in the resistant beet. Any one or a combination of these factors may account for the behavior of strains 1 and 3 in sugar beet plants. The data indicating that virus concentration of a strain is not reduced by the introduction of a second strain into the same host would lend support to the idea that competition for nutrients is not the important factor.

Infection of a sugar beet plant by one virus strain does not appear to retard the development of subsequent infection by a second strain.

The concentration of one strain of virus in a sugar beet plant seems to be approximately the same whether it is the only one in that host or there are two present.

The frequent predominance of the less virulent strains of curly-top virus in the early spring may be accounted for by the fact that extreme injury or death occurs to so many of the overwintering annual hosts which become infected by the more virulent strains. Among the more virulent strains the occasional predominance of 3 may well be accounted for by its ability to attain dominance when maintained for some months in a susceptible host.

When a given leafhopper infects successive sugar beet plants of the same variety some of the plants may develop severe symptoms while others develop only mild symptoms. This might indicate a variation in the host plant but in many cases it is undoubtedly due to the fact that the leafhopper has ingested two or more strains of the virus and that one of them is temporarily dominant in the host or that the symptoms of the more virulent strain have masked the symptoms of the less virulent strain. It has been shown that plants inoculated with a mixture of a less virulent strain and a more virulent strain may show only mild symptoms for two or more weeks and then suddenly develop severe symptoms and tests from many such plants have proven that the more virulent virus could be recovered from many (16%) of them and it was doubtless present in many more.

The experimental work discussed in this report helps to explain some of the puzzling observations which have been encountered in the field.

Effect of Fertilization on Recovery of Transplanted Diseased Sugar Beet Seedlings Under Greenhouse Conditions[1]

M. M. AFANASIEV

ABSTRACT[2]

One month old diseased sugar beet seedlings grown in the greenhouse and transplanted to other soil flats fertilized with various combinations of nitrogen, phosphorus, potassium, and manure showed remarkable ability for recovery, especially in flats which received complete fertilization or manure. Diseased seedlings grown in well-fertilized soil produced large sized plants. The seedlings grown in soil fertilized with nitrogen, phosphorus, and potassium alone, or grown in the check soil, remained very small. A row of healthy beet seedlings and two rows of diseased seedlings were planted in each flat of soil.

These experiments show that if the fertility of the soil is low and the beet seedlings show a considerable amount of disease, the situation can be improved by an early application of nutrients.

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[2] This paper in complete form was published in Phytopathology: 39:1001-1004. 1949.

Continued Greenhouse Experiments in Row Treatment of Soil for Control of Blackroot of Sugar Beet Seedlings[1]

A. A. HILDEBRAND, W. E. McKEEN AND L. W. KOCH[2]

In 1947 and again in 1949 at these meetings, and in a comprehensive paper[3] which was published in April, 1949, the research which had been carried out at Harrow up to about a year ago was reported in full detail both as to methods employed and results obtained. It will be necessary, therefore, at this time only to recall that, as the result of a large number of screening tests, employing the method of row application of the material under test, certain formulations containing tetramethyl thiuram disulphide (hereinafter referred to as T.M.T.D.) as the lethal agent had been found to be most consistently effective in the control of blackroot of sugar beet seedlings. The investigations up to the time in question had focused attention on Arasan at a recommended dosage rate of from 3 to 4 lb. per acre on the linear-foot basis. With Arasan costing about one dollar per lb., the cost of producing sugar beets is increased by some three to four dollars per acre. While this increase in cost is by no means prohibitive, nevertheless, it was realized that, in any case, the search should be continued for another material or other materials which might be as efficaceous as Arasan and at the same time less expensive whether because of lower cost or smaller dosage rate. These latter considerations were given added importange by a report[4] that in Colorado row application of Ceresan M at 1 lb. per acre was as effective as 4-lb. applications of Arasan in bringing about a 60% increase in the number of healthy sugar beet seedlings. This report that Ceresan M can be effective at one quarter the amount of the more costly Arasan suggested implications so highly important from the practical standpoint that comparative trials were undertaken immediately. The results obtained are discussed below.

Further in regard to differences in effectiveness between different chemicals or formulations of a given chemical, it was noted some time ago in the Harrow trials that row applications of D-419 at 2 and 3 lb. per acre compared favorably with 4-lb. applications of Arasan. D-419, a formulation supplied by a firm manufacturing agricultural chemicals, contains, as does Arasan, 50% T.M.T.D. as the lethal agent. The comparison between these two products is dealt with below.

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[1] Contribution No. 1,008 from the Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.

[2] Plant Pathologist, Associate Plant Pathologist, and Senior Pathologist-in-Charge, respectively.

[3] Row treatment of soil with tetramethyl thiuram disulphide for control of blackroot of sugar beet seedlings. I. Greenhouse tests. A. A. Hildebrand, W. E. McKeen, and L. W. Koch. Can. Jour. Research, C, 27: 23-43. April, 1949.

[4] DuPont Seed Treating News, August-September, 1949.

Of especial interest to this group, we believe, have been the results obtained within the past year with a chemical to which has been ascribed no particular fungicidal properties but which has long been recognized as furnishing to plants for their metabolism one of the important, so-called minor elements. Borax (sodium tetraborate) is the chemical and its inclusion in our trials came about as follows:

In May, 1949, following intimations from officers of the F. and M. Beet Sugar Assn., and from officials of the Michigan Sugar Co., that seedlings were showing an unusual trouble, we visited a number of fields in the Saginaw area in which the seedlings were showing leaf yellowing and leaf-tip necrosis. We were especially concerned because Arasan, which had been added to the fertilizer for the control of blackroot, was suspected in some degree, at least, as being the cause of the trouble. However, we were able to assure those concerned that the symptoms in question were quite different from any we had ever encountered at Harrow in connection with the use of Arasan. Evidence pointed rather to boron as the possible cause of the trouble, especially since borax, also mixed with the fertilizer, had been applied in the beet rows at concentrations perhaps a little higher than the seedlings could withstand.

Immediately, at Harrow, a series of tests was set up in which Arasan alone, borax alone, and the two chemicals together mixed in varying concentrations with a standard commercial fertilizer, were employed. In June, the interested Michigan officials visited our laboratory and, in certain of the tests in which borax had been used at higher concentrations, they recognized seedlings showing symptoms exactly as they had appeared in the Michigan fields. At the same time there was opportunity of distinguishing between boron-induced symptoms and those associated with Arasan toxicity. What is of greater significance so far as the main interests of this paper are concerned was the discovery in those trials that borax was exerting a decidedly modifying effect on blackroot.

During the past year, attention has been concentrated, then, on trials involving the four chemicals Ceresan M, D-419, borax, and Arasan. Each trial extended over a period of five weeks and most of them were repeated three times. The tests had necessarily to be carried out at different times of year with consequent variations in temperature and light intensity. The soil used was a naturally-infested Brookston clay loam in which, without fungicidal protection, mortality averaged about 50% of emerged seedlings. The primary pathogen involved was the water-mould fungus, *Aphanomyces cochlioides*. In all series including check, a 2-16-(6, 8 or 10) commercial fertilizer was added at the rate of 400 lb. per acre, 200 lb. with the seed and 200 lb. below the seed. U. S. 215x216 seed either segmented or processed was used, the segmented having a germinating capacity of about 109%, the processed about 160%. Standardized methods and techniques, as described in the earlier reports referred to above, were employed throughout.

Comparison of Ceresan M with Arasan

The results obtained in comparative tests between Ceresan M and Arasan are summarized in Table I, the figures in this table representing the

averages for three different experiments carried out in July, September and November, 1949, respectively. Three flats comprised the test unit in each trial.

Table 1.—Effect of row treatment with Ceresan M and with Arasan on emergence of seedlings and incidence of blackroot.

Per Acre TMT (lb.)	Emergence %	Emergence Incr. Over Ck. %	% Blackroot	Final Seedling Stand No. per foot	Final Seedling Stand Incr. Over Ck. %
Check	59.3		44.1	8.0	
4 Ar.	88.5	29.2	7.6	19.5	144.7
1 Cer. M.	90.4	31.1	14.1	17.9	123.7
2 Cer. M.	89.8	30.5	10.2	19.1	139.6
3 Cer. M.	83.1	23.8	5.0	18.9	136.2
4 Cer. M.	73.8	14.5	2.8	17.2	115.0

Table 1 shows that, numerically, there is little difference in germination between Arasan at 4 lb. and Ceresan M at 1 and 2 lb. Daily increments of germination plotted on a graph showed that at 1 lb. Ceresan M rate of emergence equalled that of Arasan but at 2 lb. of Ceresan M a slight lag was apparent. At 3 lb. Ceresan M, emergence was definitely delayed and some seedlings were dwarfed noticeably. In controlling blackroot, Arasan was slightly more effective than Ceresan M except at 3 and 4 lb. of the latter, but at these concentrations toxicity very definitely entered the picture. In the Arasan series the general observation has been that most of the seedlings which die do so relatively early in the experiment, whereas in the Ceresan M series, the seedlings continue to die throughout the 5-week period of the trials. Thus, there is the suggestion that Ceresan M may not have the carry-through protective effect which Arasan has always displayed.

Another observation was that seedlings grown in Ceresan M-treated soil were larger, more succulent, and, as they grew older, tended to "flop over" more readily than those in corresponding Arasan series. Whether these characteristics would appear under outdoor conditions and, if so, whether or not they would be more or less desirable from the cultural stand-

Table 2.—Effect of row treatment with borax (boron) and with Arasan on emergence of seedlings and incidence of blackroot.

Per Acre TMT (lb.)	Emergence %	Emergence Incr. Over Ck. %	% Blackroot	Final Seedling Stand No. per foot	Final Seedling Stand Incr. Over Ck. %
Check	75.1		42.4	9.9	
4 Ar.	112.9	37.8	3.9	24.7	147.6
5 B	100.8	25.7	19.9	19.4	94.6
7 B	88.2	13.1	7.8		

point can only be determined by field experiments. Such are being planned for next summer. At the moment we do not see that Ceresan M has any particular advantage over Arasan.

Comparison of borax (boron) with Arasan

In tests with borax the chemical was applied at rates ranging from 3 to 30 lb. per acre. However, in Table 2, only the results which were obtained with two critical rates of application are shown.

From Table 2 it will be noted that although emergence at the 5-lb. application of borax was 12% below that of the standard Arasan treatment, nevertheless, the increase over check was 25.7%. This latter difference in favor of the borax would suggest that the chemical was affording the young seedlings considerable protection against the pre-emergence phase of the disease. Whether the effect was on the host or on the parasite remains to be discovered. In the borax series up to and including the 5-lb. application, emergence was usually—but not invariably—slightly more rapid than in the Arasan series. It was noted, too, that seedlings growing in the borax-treated soil were more vigorous than those in the check or Arasan series. The seedlings were very tolerant to borax at the 5lb. application—much more so, for example, than a species of grass which appeared in the flats. Blades of this grass which grew up in the sugar beet rows were almost entirely chlorotic and many of them died. At 7 lb., borax was becoming decidedly toxic to the seedlings.

Table 3.—Effect of row treatments with mixtures of Arasan and borax, with Arasan alone and with borax alone on emergence of seedlings and incidence of blackroot.

Per Acre TMT (lb.)	Emergence %	Emergence Incr. Over Ck. %	Disease % Blackroot	Disease % Tox.	Disease % Total	Final Seedling Stand No. per foot	Final Seedling Stand Incr. Over Ck. %
Check	93.9		65.4		65.4	7.7	
3 Ar	156.8	62.9	10.6	1.5	12.1	33.0	325.8
4 Ar	159.8	65.9	7.9	6.0	13.9	33.0	325.2
3 Ar + 4 B	165.6	71.7	11.3	2.5	13.8	34.1	339.2
3 Ar + 5 B	151.3	57.4	12.0	4.2	16.2	30.3	290.7
4 Ar + 4 B	154.7	60.8	9.5	7.1	16.6	30.9	297.6
4 Ar + 5 B	154.7	60.8	4.0	8.7	12.7	32.4	316.9
4 B	132.3	38.4	57.0		57.0	14.1	82.4
5 B	141.9	48.0	38.6		38.6	20.9	109.6

Table 2 shows that incidence of blackroot at the 5-lb. application of borax was 16% higher than in the Arasan series but 23.5% lower than in check. Of special interest is the fact that, after 5 weeks, the stand of seedlings in the borax-treated soil exceeded that in the check by 94.6%. In the borax, as in the Ceresan M series, dying of the seedlings continued throughout the period of the experiment.

Based on our experimental results to date, it would appear that appreciable beneficial results may be expected from an application of 5 or 6 lb. per acre of borax along with the regular fertilizer.

Comparison of mixtures of Arasan and borax with Arasan alone and borax alone

Having observed that borax had an apparently stimulating or protecting effect on sugar beet seedlings, it seemed advisable to mix that chemical with Arasan and thereby possibly combine a fungicidal with a stimulatory effect. Results of tests along these lines are summarized in Table 3.

Table 3 shows that maximum germination was obtained in the 3 Arasan plus 4-lb. borax treatment. However, the difference among the six treatments 3 Arasan . . . 4 Arason plus 5 borax are not great and, if the results were analyzed statistically, the differences might be found to lack significance. It

is interesting to note that the 4- and 5-lb. treatments with borax alone gave increases of 38.4 and 48%, respectively, over check.

In regard to incidence of blackroot, a loss of 65.4% of the seedlings in the check series gives a measure of the "disease potency" of the soil. This potency, it will be noted, is very much reduced in both the Arasan and the Arasan-borax series. When Arasan was used at 3 and 4 lb. (with or without borax) incidence of blackroot averaged 11.3 and 7.1%, respectively. A 4-lb. application of borax had only a slightly modifying effect on the disease but the 5-lb. application was better than check by 26.8%.

Table 4.—Effect of row treatment with D-419 and with Arasan on emergence of seedlings and incidence of blackroot

Per Acre TMT (lb.)	Emergence %	Emergence Incr. Over Ck. %	% Blackroot	Final Seedling Stand No. per foot	Final Seedling Stand Incr. Over Ck. %
Check	49.9		45.6	6.4	
4 Ar	99.3	49.4	8.5	21.7	236.3
2 D-419	102.0	52.1	13.8	22.1	241.5
3 D-419	101.4	51.5	9.8	21.8	238.3
4 D-419	94.9	45.0	8.1	21.0	225.3

In tests in which more-recently-acquired Arasan has been used, a toxicity factor that is having a bearing on results has been encountered. As shown in Table 3, it has been necessary to recognize in Arasan-treated soil an appreciable number of seedlings as showing definite toxicity symptoms. More seedlings are affected by a 4lb. than by a 3-lb. treatment with the chemical. Formerly Arasan was used with impunity at 4 lb. per acre and the toxicity factor was negligible. Our tests are being carried out in the same environment as formerly and the technique has not changed. Arasan is still, of course, as the data show, affording phenomenal protection to the seedlings under greenhouse conditions.

Final stand of seedlings it will be noted was highest for the 3 Arasan plus 4-lb. borax treatment and very much better for the 5-lb. borax treatment than for check.

Comparison of D-419 with Arasan

As mentioned above, D-419 is a formulation containing as does Arasan, 50% T.M.T.D. Because the two formulations contain an equal amount of the lethal agent, it might be expected that they would produce exactly the same results. However, from the time that the two chemicals were compared in parallel tests a difference was noted. For want of a better term, we spoke of D-419 a being "stronger" than Arasan. For example, a 4-lb. treatment with D-419 always resulted in toxicity to seedlings whereas a similar application with the Arasan used earlier in the investigations did not. As will be pointed out by Dr. McKeen in the paper which follows immediately, the differences between D-419 and Arasan which have been observed in the greenhouse have apparently carried through under field conditions. Results of parallel tests carried out in the greenhouse are summarized in Table 4.

As Table 4 shows, the 2-lb. treatment with D-419 gave highest emergence and slightly highest final stand of seedlings but did not control blackroot quite as effectively as Arasan at 4 lb. or D-419 at 3 lb. The latter compound at 4 lb. reduced germination and induced toxicity in seedlings.

Briefly, the findings as presented above may be summarized as follows:

In continued greenhouse tests at Harrow, Ontario, the effectiveness of Ceresan M, borax, and D-419 (a proprietary formulation containing 50% tetramethyl thiuram disulphide) has been compared with that of Arasan in controlling blackroot of sugar beet seedlings. Results obtained with Ceresan M and with borax at rates of 2 and 5 lb. per acre, respectively, have been so favorable as to warrant field trials with these two chemicals. D-419 has been found not only to equal Arasan but, in certain respects, to be preferable to the latter compound.

Field Results In 1949 Following Row Treatment of Soil with Tetramethyl Thiuram Disulphide for Control of Blackroot of Sugar Beet Seedlings[1]

A. A. HILDEBRAND AND W. E. McKEEN[2]

In 1949 field tests were carried out in a number of locations in Kent county, the centre of the sugar beet-growing area of southwestern Ontario, but finally, for economy of time and effort and for greater precision in the obtaining of results, attention was concentrated on one six-acre field. This field, which was not too well under-drained, had a definite, recent blackroot history. The soil, a Brookston clay loam, was known to have produced some eight or nine crops of beets within the past 20 years and, in 1948, the seedling stand had been lost due to blackroot. A field more favorable for our tests could scarcely have been found.

The field was planted under ideal weather and excellent seed-bed conditions on May 5. For seeding operations and for deposition of fertilizer and fungicide-fertilizer mixtures an Oliver-Superior drill was used, the latter being drawn by a small tractor at a uniform rate approximating three miles per hour. The Oliver-Superior drill did not permit as ideal placement of the fertilizer as desired—namely, in the zone intervening between the seed level and the surface of the soil—but, of the drills available, it was closest suited to our purpose. Generally speaking, it deposited the fertilizer in an irregular pattern in the seed furrow above the seed. The weakness of this placement lay in the fact that a zone between the ground surface and the fertilizer level was left without fungicidal protection. U. S. 215x216 processed seed was planted to a depth of about 1¼ to 1¾ in., in rows 28 in. apart, the rows being some 540 ft. long. No individual test comprised less than 16 rows running the full length of the field.

Every effort was made to apply the fungicide-fertilizer mixture in amounts approximating as closely as possible those which had given best results in the greenhouse experiments. Known weights of the various mixtures were added to the drill box and known distances were covered. Thus, it was easy to calculate the exact rates of application of any given material under test. Details as to materials used and rates of application are indicated in Table 1.

Cultural operations were carried out by the cooperating grower and by labor supplied by the Canada and Dominion Sugar Company, Chatham, Ontario. Prior to blocking and thinning and then subsequent to these opera-

[1] Contribution No. 1,009 from the Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.

[2] Plant Pathologist and Associate Plant Pathologist, respectively.

Table 1.—Effect of row treatment of different formulations containing T.M.T.D. on stand of seedlings and yield of mature beets

Test	Treatment (per acre basis)	No. of seedlings per row (average) Pre-thinning counts	% Increase	Post-thinning counts	% Increase	Yield of Beets Tons per acre	Tonnage Increase	% Increase
1	432 lb. 2-12-6	1519	37.4	331	22.6	12.62	.81	6.4
	432 lb. 2-12-6 containing 4.3 lb. Arasan	2087		406		13.40		
2	218 lb. 2-12-6	1734	34.7	319	15.8	9.16	.36	3.8
	218 lb. 2-12-6 containing 4.3 lb. Arasan	2336		370		9.52		
3	388 lb. 2-16-6	1467	44.6	293	12.4	9.04	2.20	24.2
	388 lb. 2-16-6 containing 2.6 lb. D-419	2122		330		11.24		
4	324 lb. 2-16-6	1192	61.3	260	21.1	8.26	1.55	18.1
	324 lb. 2-16-6 containing 3.2 lb. D-419	1923		314		9.81		
5	302 lb. 2-16-6	1562	37.6	262	37.6	7.90	3.43	43.4
	302 lb. 2-16-6 containing 4 lb. D-419	2273		357		11.30		

tions, we made counts of seedlings and compared the number in treated (fungicide and fertilizer) and in untreated (fertilizer alone) rows. Some 141,000 seedlings in more than eight miles of row were counted, the results being as shown in Table 1. Rows to be counted were in all cases selected at random before entering the field.

In mid-October the beets were lifted and topped in the prescribed manner. In our tests in previous years, sections of rows were harvested and weighed. This year yields from complete rows were weighed and compared. This involved the handling of about 25.5 tons of beets taken from 88 treated and untreated rows, representing an aggregate of nine miles of beet row. Both from the standpoint of magnitude and accuracy of the various operations involved, we believe that our field tests this year have not been surpassed by any similar experiment.

As Table 1 indicates, both pre- and post-thinning counts of seedlings showed increased stands in rows which had received the fungicide-fertilizer mixture. Especially in the pre-thinning counts the advantage lay definitely with D-419, an application of this formulation at 3.2 lb. per acre in one instance resulting in an increase in stand of 61.3% over corresponding check rows.

The increases in the early stands of seedlings in treated rows was reflected in increased yields of mature beets. Here again, as Table 1 clearly shows, D-419 gave results much more impressive than those obtained with Arasan. As a matter of interest, it may be stated that blackroot was worst in the section of the field where the D-419 tests were carried out. Since this is the first year that D-419 has been tested in the field, we have nothing on record with which to compare this year's results. However, in the case of Arasan, we can make broad comparisons between this year's and last year's field results. In 1948, in two widely-separated tests, Arasan applied at the rate of 3¾ lb. per acre in each gave increases of 1.5 and 1.3 tons per acre, respectively. This year, best results following the use of Arasan at 4.3 lb. per acre showed an increased yield of only .81 tons per acre.

Despite the generally successful use of Arasan-impregnated fertilizer, we are aware of instances in Ontario in which blackroot occurred in fields to which the protectant has been applied. There are a number of reasons why this occurred in 1949 and may occur again in the future. Chief of these, however, we believe, is improper placement of the protectant. We are insistent on the point that the seed should germinate in and grow up through soil impregnated with fungicide. We believe further that as the methods for field application approach more closely in precision those employed in the greenhouse, greater success in the control of the disease may be expected.

In closing, the content of the present paper may be recapitulated briefly as follows:

In field tests in which formulations of tetramethyl thiuram disulphide mixed with standard commercial fertilizer were added to field soils with a recent, definite blackroot history, non-thinned stands of seedlings receiving the T.M.T.D.-fertilizer mixture exceeded those receiving the fertilizer alone by from 34.7 to

61.3%. Furthermore, counts made subsequent to blocking and thinning operations showed gains for the treated rows over the untreated of from 8 to 35%. Such differences in early stands of seedlings have been reflected in increases of mature beets, which range from .36 to 3.43 tons per acre, in accordance not only with the rate of application of the chemical but also with the particular formulation of the latter.

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Chemistry and Factory Operations

American Beet Sugar in 1775?

H. W. DAHLBERG[1]

All sugar technologists are familiar with the fact that Achard, the famous chemist, was the first European to produce beet sugar in some quantity in the year 1802. Without detracting in any way from his well-deserved fame as a plant breeder and sugar chemist, there may be just a little doubt that he was the first man to produce beet sugar in quantity for food purposes.

This doubt springs from the fact that Spanish historical records show that the Indians of the Santa Clara valley of California were producing sugar from some vegetable source prior to 1775. The original manuscript, dated November 20, 1775, describing these facts is preserved in the Mexican Archives, Museo Nacional, Mexico City, and a signed contemporary copy dated November 30, 1775, is in the Spanish archives at Seville, Spain, so there can be no doubt as to the authenticity of the record. The title of the manuscript (translated) is "A Historical, Political and Natural Description of California" by Pedro Fages.

Pedro Fages, a Spanish captain, explored Sonora and lower California in 1768 and 1769. He was in command of a military force which reached San Diego on May 1, 1769, and he explored the country around Alameda in 1770 and again in 1772. He served as governor of California from September 10, 1782, to April 16, 1791, and is considered one of the ablest, if not the outstanding, governor of the Spanish period.

Pedro Fages' manuscript shows that as an explorer he was a careful observer of the habits and customs of the Indians who lived in California at that time. He mentions the following materials as being common articles of food used by the Indians—rice, acorns, onions, cattail seeds, laurel berries. Fages' manuscript has been translated by Professor H. I. Priestley of the University of California and makes a very interesting little book of about 100 pages. I am indebted to the Bancroft Research Library of the University for the original Spanish quotation of a significant paragraph of the manuscript, together with a literal translation, which reads as follows: *"Hacen tambien los de la Sierra cantidades de melcocha, y azucar, que no desmerece el nombre para aquellas gentes, y ser sacadas estas especies de unos begetales, que de suyo no parecen prometer tanto."* The translation of the above is as follows: "Those (the tribes) of the Sierras make also quantities of molasses candy, and sugar, that is not unworthy of the fame of these peoples, and it is extracted from certain species of vegetables, which of themselves do not appear to promise much."

There are several reasons for believing that the "vegetables" mentioned by Fages were some type of sugar beet. First of all, the Spanish words for "vegetable" and "fruit" are quite different, and Fages uses the word "fruit" in other parts of the manuscript in which he describes another source of sugar. There is, therefore, no question but that Fages was describing a vegetable and nothing else when he used this word.

For many years there has been growing in the Milpitas-San Jose area of the Santa Clara valley and also near Hollister, California, a variety of

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sugar beets which is an annual and produces seed every year. These beets resemble quite closely some of the annual types of sugar beets which grow on the shores of the Mediterranean and I believe they had their origin there, rather than as escapes from early sugar beets introduced into California when the industry was established there about 1870.

It is quite possible that some type of sugar beets may have been introduced into California as early as the 16th century or later during some of the Spanish expeditions between Mexico and California. Upper California was discovered by Cabrillo in 1542 and Sir Francis Drake landed in California in 1579. Many other explorers followed these two. It seems to have been the custom of some of these navigators and explorers to carry seeds and fruits from place to place. It is recorded in the history of the Franciscan missions that Galvez in 1769 "packed seeds of all useful plants" for the establishment of Mission gardens in California. It is also well known that many varieties of beet were used for food in Italy and the Mediterranean area even before the birth of Christ.

Among the reasons for believing in the Mediterranean origin of early California beets, and of the present wild types growing at Milpitas and Hollister, are the following:

1. **The present beets are distinct annuals, which is also true of many of the Mediterranean types.**
2. **Both the root type and the plant above ground are very similar to the Mediterranean type.**
3. **The present Milpitas beets have a high resistance to *Cercospora* (leaf spot), similar to that found by Munerati in wild beets growing in the estuary of the Po river in Italy. This character would not be found in the German commercial varieties of seed used in California in 1870 and later.**

If it is true that the "vegetables" used by the Santa Clara Indians for sugar production were some Mediterranean type of sugar beet, there was ample opportunity for seeds of this type to have been brought from Spain or Mexico to California in some expedition between the time of Cabrillo and the time of which Fages wrote in 1775. It is hoped that further research in old Spanish manuscripts may throw further light on the question.

As a matter of interest, and showing how familiar the early Indians of California were with sugar, I wish to quote the following from Fages' manuscript, in which he describes another source of sugar in another section of California (not the Santa Clara Valley)—"Native sugar is made from the olive-like fruit produced by a very leafy tufted shrub six feet high with a stem of reddish color and leaves like those of the mangrove. The preparation of the sugar consists in gathering the ripe fruit, separating the pulp from the seed, and pressing it in baskets to make cakes of sugar when dry and of good consistency."

The above quotation is interesting because it shows that Fages knew very well that "vegetables" were the source of sugar in the Santa Clara valley and that "fruits" were the source in another section of California.

Some evidence has been submitted in this paper that the "vegetables" mentioned by Fages may have been sugar beets, and that beet sugar may possibly have been made in California some 27 years earlier than Achard's work. Further historical research on the subject would be very desirable.

Scale Reading–Brix Conversion Table for the Bausch and Lomb Precision Refractometer in the Normal Weight Solution Method of Analysis of Sugar Products

F. W. WEITZ[1]

The adaptation of the Bausch and Lomb precision sugar refractometer for use in the *Normal Weight Solution Method of Sugar Analysis* described by Bachler (1)[2] for routine determination of Brix of Original Product requires the construction of a special scale reading—brix conversion table, fitted for the instrument scale, supplementing the basic set of tables furnished by the instrument makers for conversion of scale readings to percent sugar in solution.

An element to be recognized in connection with the construction of such tables is the fact that one general table is not universally applicable for all instruments of this type. The table must be adapted to the specific refractive index characteristics of the particular series number prism with which the instrument is provided. The separate lots of prisms cut from glass of different melts are marked for series identification by three digit numbers comprising the last three figures of the index value for sodium light of the particular glass. For example, prisms cut from a lot of glass of a given melt having an index of 1.51716 are identified by the three digit numbers 716. The instrument for which the set of tables herein described was made up is one of a group with prisms of this series, number 716. For the group of instruments of a like numbered prism series one set of tables will be applicable in common, but for each group of a differently numbered prism series a separate set of tables must be made up.

The scale is uniform on all refractometers of the precision type and is graduated in equi-divisions numbered 0 to 72, with the whole numbered divisions subdivided equally into tenths. By means of a vernier the scale setting is read to one tenth of the smallest subdivision, or to one hundredth of a scale unit. The scale reading for the setting on distilled water, $n\frac{20^{\circ}}{D}$ 1.33299, is in the range of about 21, and the setting for a sugar solution containing 26 grams of dry sugar solids in 100 ml reads on the scale approximately 28. The exact scale division reading values for either distilled water or the normal weight sugar solution depend on the particular prism series.

The table furnished by Bausch and Lomb is identified by like series number with the series number of the prism of the particular instrument,

[1] General Chemist, American Crystal Sugar Company, Denver, Colorado.
[2] The numbers in parentheses refer to literature cited.

Table 1.—Conversion of Scale Readings, B & L Precision Sugar Refractometer, on Normal Weight Sugar Solutions at 20° C. into Brix of Solution and Brix of Original Product. —Prism Series 716.

Scale Reading		21.11	21.20	21.30	21.40	21.50	21.60	21.70	21.80	21.90
Brix of Solution		.00	0.35	0.73	1.11	1.49	1.87	2.24	2.62	3.00
Brix Orig. Prod.		.00	1.31	2.79	4.27	5.74	7.21	8.68	10.15	11.62
Scale Reading	22.00	22.10	22.20	22.30	22.40	22.50	22.60	22.70	22.80	22.90
Brix of Solution	3.37	3.74	4.10	4.47	4.84	5.20	5.57	5.93	6.29	6.65
Brix Orig. Prod.	13.09	14.55	16.01	17.47	18.93	20.38	21.84	23.29	24.74	26.19
Scale Reading	23.00	23.10	23.20	23.30	23.40	23.50	23.60	23.70	23.80	23.90
Brix of Solution	7.01	7.36	7.72	8.07	8.42	8.78	9.13	9.47	9.82	10.17
Brix Orig. Prod.	27.64	29.08	30.53	31.97	33.41	34.85	36.28	37.72	39.15	40.58
Scale Reading	24.00	24.10	24.20	24.30	24.40	24.50	24.60	24.70	24.80	24.90
Brix of Solution	10.52	10.86	11.20	11.54	11.87	12.21	12.54	12.88	13.21	13.54
Brix Orig. Prod.	42.01	43.44	44.86	46.29	47.71	49.13	50.55	51.96	53.38	54.79
Scale Reading	25.00	25.10	25.20	25.30	25.40	25.50	25.60	25.70	25.80	25.90
Brix of Solution	13.87	14.20	14.53	14.85	15.18	15.50	15.82	16.14	16.46	16.78
Brix Orig. Prod.	56.20	57.61	59.02	60.42	61.83	63.23	64.63	66.03	67.42	68.82
Scale Reading	26.00	26.10	26.20	26.30	26.40	26.50	26.60	26.70	26.80	26.90
Brix of Solution	17.10	17.42	17.74	18.05	18.36	18.67	18.98	19.29	19.60	19.90
Brix Orig. Prod.	70.21	71.60	72.99	74.38	75.76	77.15	78.53	79.91	81.29	82.67
Scale Reading	27.00	27.10	27.20	27.30	27.40	27.50	27.60	27.70	27.80	27.90
Brix of Solution	20.21	20.51	20.81	21.12	21.42	21.72	22.02	22.32	22.62	22.91
Brix Orig. Prod.	84.04	85.41	86.78	88.15	89.52	90.89	92.25	93.61	94.97	96.33
Scale Reading	28.00	28.10	28.17							
Brix of Solution	23.20	23.50	23.70							
Brix Orig. Prod.	97.69	99.04	99.99							

or group of instruments, for which it is applicable. The table gives the percent sugar in solution equivalent to scale readings at the temperature of 20° C., by steps of tenths of scale units. Where the solution is made up on the basis of 26.00 grams of sugar product in 100 ml at 20° C. the table values for percent sugar are the values for the Brix of the Normal Weight Solution. These values from the Bausch and Lomb conversion table (2) were transcribed directly as the basis of the Table for Brix of Normal Weight Solution. By simple interpolation between contiguous tenths of scale units the table was expanded to show Brix of Normal Weight Solution by units of one hundredth of scale degrees.

The values for Brix of Normal Weight Solution equivalent to scale readings constitute the basic data for the calculation of the secondary table

to show Brix of Original Product. The Table for Brix of Original Product, applicable when the solution contains 26.00 grams of sugar product, weighed in air and made up to 100 ml at 20° C., is constructed of values computed by the following general formula (3):

$$\text{Brix Orig. Product} = \frac{\text{Brix N. Wt. Sol. x Sp. Gr. } 20°/4° \text{ C x } 100}{26.00\ (1 + 0.001\ k)} \qquad (I)$$

The factor k is a variable, varying with the density of the product, in the reduction of weight of sample in air to weight in vacuo (4). The density determinant for the appropriate k factor is established from an approximated value for the actual value of the Brix of Original Product. The approximated Brix is derived by applying the known values in the above formula (I) but omitting from the divisor the reduction factor (1 + 0.001 k). From the approximated Brix value the density of the product is established by reference to the table of density of sugar solutions at 20° C.

A table for Brix of Original Product, correlated, with the table for Brix of Normal Weight Solution, to scale readings, was compiled for the prism series 716. By the formula as given above (I), a provisional value for Brix of Original Product equivalent to the scale reading was computed for each one tenth scale unit over the range from distilled water reading to the reading of the normal weight solution of pure sucrose. The procedure of calculation may best be clarified by illustration with an example as follows:

Scale reading	**27.70**
Brix of Normal Weight Solution	**22.32**
Sp. Gr. of solution 20°/4° C. (Sp. Gr. Table)	**1.09134**
Dry Substance in 100 ml, Weight in Vacuo	**24.35871**
Approximate Brix of Original Product	**93.69**
Density of product (Plato's Table)	**1.506**
k factor (Table 108, N. B. S. Cir. C440)	**0.657**
Brix of Original Product, provisional	**93.626**

The provisionally established values for Brix of Original Product require minor adjustment for leveling off slight irregularities in the progressive increments for increasing scale readings. The values for percent sugar as given in the Bausch and Lomb conversion table, which were translated to the prepared table as the basic values of Brix of Normal Weight Solution, are the sucrose equivalents of the index of refraction corresponding to the scale readings. These values for percent sugar are interpolated from the 1936 International Table of Refractive Indices for Sugar Solutions at 20° C. and are rounded to the second decimal. The magnitude of deviation on rounding may be of the order of ± .005 Brix. As the ratio of the Brix of the Normal Weight Solution to the Brix of Original Product is approximately 1:4, the calculated value provisionally established for the Brix of Original Product may show deviation from the most probable value by as much as 4 times ± 0.005 or ± 0.02 Brix. Other slight deviations in the table from what would appear to be a normal smooth curve in the relationship of scale reading to percent sugar may offset the calculated

Brix of Original Product value by as much as ± 0.04 in some instances. The effect of these deviations is a table of computed values of Brix of Original Product showing slight irregularities from a smooth curve of progressive increments of Brix for uniform stepwise increments of scale units.

To correct for these apparent discrepancies the provisional values established by calculation from the general formula for Brix of Original Product were adjusted to a smooth curve by recalculation from the normal equation to the line of best fit derived by the method of least squares. Plotting the

Table 2.—Temperature Corrections for Scale Readings on Bausch and Lomb Precision Sugar Refractometer, Standard at 20° C.—Prism Series 716.

Temp. °C	Scale Reading 21.11	22	23	24	25	26	27	28	29	Temp. °C
					Subtract from the Observed Scale Reading					
18.0	0.031	0.034	0.036	0.038	0.041	0.043	0.046	0.048	0.051	18.0
.5	.023	.025	.027	.028	.031	.032	.034	.036	.038	.5
19.0	.016	.017	.018	.019	.021	.022	.023	.024	.026	19.0
.5	.008	.008	.009	.010	.010	.011	.012	.012	.013	.5
					Add to the Observed Scale Readng					
20.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	20.0
.5	.008	.009	.009	.010	.011	.011	.012	.013	.013	.5
21.0	.017	.018	.019	.020	.021	.023	.024	.025	.026	21.0
.5	.025	.027	.028	.030	.032	.034	.036	.038	.039	.5
22.0	.033	.036	.038	.040	.043	.045	.048	.050	.053	22.0
.5	.042	.045	.048	.051	.054	.057	.060	.063	.066	.5
23.0	.051	.054	.058	.061	.065	.068	.072	.076	.079	23.0
.5	.060	.064	.068	.072	.076	.080	.085	.089	.093	.5
24.0	.069	.073	.078	.083	.088	.092	.097	.102	.107	24.0
.5	.078	.083	.088	.094	.099	.104	.110	.116	.121	.5
25.0	.088	.093	.099	.105	.111	.117	.123	.129	.135	25.0

Brix values against scale reading shows the relationship to be described by a slightly curved line of the parabola type. The most probable values fitted to the curve were computed from the formula of a second degree equation to a curve of the parabola type. In its generalized form this is expressed (5) as

$$y = a + bx + cx^2$$

where, for the curve in this case,

x = Scale reading in increments of 0.1, and

y = Provisional values of Brix of Original Product as computed by formula (I) for scale readings x.

Following common procedures of statistical analysis in computing trend lines, the values of a, b and c for substituting in the formula may be derived

by resolving simultaneously from the relationship expressed in the equations

$$\begin{aligned} \Sigma\ (y) &= na + b\ \Sigma\ (x) + c\ \Sigma\ (x^2) \\ \Sigma\ (xy) &= a\ \Sigma\ (x) + b\ \Sigma\ (x^2) + c\ \Sigma\ (x^3) \\ \Sigma\ (x^2y) &= a\ \Sigma\ (x^2) + b\ \Sigma\ (x^3) + c\ \Sigma\ (x^4) \end{aligned} \qquad \text{(III)}$$

n= number of items of paired data. In this case n = 71 = the number of correlated items of scale readings x and the Brix equivalents y, in 0.1 scale divisions. The scale reading divisions in 0.1 units were taken from the first whole 0.1 scale unit above the reading for water to and including the next whole 0.1 scale unit above the reading corresponding to the Brix of the Normal Weight sugar solution.

Taking advantage of a short cut procedure in the statistical analysis trend line computations, applicable where the values of x are consecutive and n is an odd number, the labor of calculations can be materially curtailed if, instead of describing the curve with origin at the scale reading for zero Brix, the origin of the curve is shifted to the median value of the scale range. In this case, n = 71, the median value is 36 in the order of sequence of consecutive items. The median scale reading value x may be represented by o and the other values of x in progression each way from the median value represented by the consecutive numbers 1 to 35, respectively, minus and plus. In that representation $\Sigma\ (x)$ and $\Sigma\ (x^3)$ become zero. The above simultaneous equations (III) then are reduced to the following simpler forms;

$$\begin{aligned} \Sigma\ (y) &= na + c\ \Sigma\ (x^2) \\ \Sigma\ (xy) &= b\ \Sigma\ (x^2) \\ \Sigma\ (x^2y) &= a\ \Sigma\ (x^2) + c\ \Sigma\ (x^4) \end{aligned} \qquad \text{(IV)}$$

Inserting the known values of the sums of the x's and y's of the indicated powers and products, the equations are solved for a, b and c. Substituting these values then in the general equation of second degree to a curve of the parabola type (II), the normal equation derived for the line of best fit for values of y, Brix of Original Product, correlated to scale reading values for x, for prism series 716, was

$$y = 51.9616 + 1.41548\ x - 0.0009022\ x^2 \qquad \text{(V)}$$

From this equation (V) the respective values of y, Brix of Original Product, for each 0.1 scale reading value x were then recalculated. The values of x representing 0.1 scale readings for inserting in the equation were the respective substituted consecutive series numbers 1 to 35, plus and minus, each way from the median value taken as 0. Intermediate values of y by steps of 0.01 scale reading for the expanded table were derived by interpolation between the computed values for contiguous 0.1 scale units. All final calculated values were rounded to the second decimal. In abridged form, for units of 0.1 scale readings, the Brix conversion table, prism series 716, is reproduced herein as Table 1.

Based on the data of Schonrock for temperature corrections on refractive index of sucrose solutions (6), a Table of Temperature Corrections on scale readings for the Bausch and Lomb refractometer was prepared, shown as Table 2. The table gives the corrections to be applied directly on observed

scale readings in the temperature range of 18° to 25° C. for adjustment to the equivalent readings at the standard temperature of 20° C.

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Control of Evaporator Scaling Through Application of Sodium Alginate Protection

FRANK N. RAWLINGS[1]

During the 1948-49 campaign the Nyssa factory conducted a campaign trial on sodium alginate scale inhibitor for its evaporators. That trial appears to have been blessed with some success so that this year the use of this protection was extended to the Nampa factory as well.

Two materials are purchased for the scale control from the Drew company, namely, evaporator concentrate and Amoroid APA-M. For addition to the juice the two items are combined together with water to give a single solution. The original recommendation was to add to the juice 3.5 parts per million, based on juice weight of each of these two materials. The addition of this solution to the juice during the 1948-49 campaign was at two points, half of it ahead of the first effect and the other half between the second and third effect.

The 1948-49 results indicated the protection was much more pronounced in the first three effects. In an attempt to carry this protection on down to the fourth and fifth effect an additional two parts per million of the straight evaporator concentrate is being added this year ahead of the fourth effect.

In setting up an evaluation of the benefits derived from this protection the comparison will be divided into two parts:

(a) The comparison covering the 1948-49 trial at Nyssa.
(b) The comparison covering the 1949-50 trial at Nampa.

Each of these trials will be seen to have its limitations. The Nyssa trial involved other simultaneous changes which had to be compensated for to arrive at a conclusion. The Nampa run is incomplete at the date of this writing.

(A) Comparison of results covering the 1948-49 trial at the Nyssa factory.

In setting up this comparison there exists the complication that Nyssa had a substantially lower lime salt content in juice during 1948-49 than for the 1947-48 campaign. This was the result of the introduction of the "Effective Alkalinity Control" for lime salts. Fortunately through the work on second carbonation studies being conducted at Nampa there was a similar condition of reduced lime salts there without the addition of sodium alginate, and through this data a correction for the reduction in boiling out attributable to lower lime salts can be made and the residue of boiling out reduction at Nyssa can then be credited to sodium alginate protection.

At Nampa during the 1948-49 campaign through close effective alkalinity control the average lime salts were 31.77% lower than for the 1947-48 campaign. As a result of this lower lime salt, the tons of beets sliced per evaporator body boiled was increased from 7,220 tons to 10,582 tons, an

[1] The Amalgamated Sugar Co.

increase of 46.6%. From this it was established that a one percent decrease in lime salts would increase the beets sliced per evaporator boiled by 1.47%.

At Nyssa the lime salts for the 1948-49 campaign were reduced 24.6%, as compared to the 1947-48 campaign. Using the Nampa factor it would have been expected that the boiling out would have been reduced at Nyssa by 24.6 x 1.47 = 36.2% if no sodium alginate had been employed. Actually the tons of beets sliced per evaporator body boiled at Nyssa were increased from 9,069 tons in 1947-48 to 15,535 tons in 1948-49, an increase of 71.3%. We can, therefore, credit to sodium alginate an increased tonnage per body boiled of 35.1% or 3,183 tons per body boiled.

The detailed comparison of boiling out on the two campaigns is as follows:

Table 1.

	1948-49 Campaign	1947-48 Campaign
Tons beets sliced	512,651	544,164
Total bodies actually boiled	33	60
Bodies boiled corrected to 1948-49 tonnage		56.53

The following table shows the comparison of the number of bodies boiled for each effect for the two campaigns.

Table 2.

Effect	1947-48 Campaign (corrected to 1948-49 tonnage)	1948-49 Campaign
1	6.59	2
2	11.31	3
3	13.19	7
4	11.31	10
5	14.31	11

It was apparent from the above figures that the reduction in boiling was greater in the first bodies. To better illustrate this, the table below calculates the tons of beets sliced for each individual body for the two campaigns and the percentage of increase.

Table 3.

Effect	Tons Beets Per Body Boiled		
	1948-49	1947-48	% Increase
1	256,326	77,738	229.7
2	170,884	45,347	276.8
3	73,236	38,869	88.4
4	51,266	45,347	13.1
5	46,605	36,278	28.5

(B) Comparison of Results covering the 1949-50 trial at the Nampa Factory to January 18, 1950.

While the campaign has not been completed at the Nampa factory at the time of this writing, the figures there for last year and this year, to the date of January 18, can be compared directly without the complication of correcting for lime salt variation. The lime salts for the two campaigns were nearly identical as shown below:

Table 4.

Year	Total Bodies Boiled	To-Date Lime Salts Thin Juice	Tons Beets Sliced	Tons Beets Sliced Per Body Boiled
1948-49	42	.034	433,846	10,330
1949-50 to Jan. 18	15	.038	333,691	22,246

* Increase in tons sliced/body boiled = 115.4%

The table below shows the comparative tonnage of beets sliced for each effect boiled last year without sodium alginate and this year with sodium alginate treatment.

Table 5.

Effect	Tons Beets Sliced per Body Boiled		
	1949-50 to Jan. 18	1948-49	% Increase
1	333,691+	216,923	
2	333,691+	114,615	
3	333,691+	108,462	
4	111,230	36,154	207.7
5	27,808	20,659	34.6

As seen above, the sodium alginate treatment this year at the Nampa factory seems to be showing greater benefit than was calculated for last year at Nyssa. It also appears this year at Nampa that the extra addition of concentrate alone into effect number four may be carrying the protection through the fourth and fifth effect to better advantage.

This sodium alginate treatment acts as a protective colloid to prevent scaling. A protective colloid can inhibit crystallization by holding the scaling salts in solution in a supersaturated state. Originally some concern was held as to whether the protective colloid would be able to hold the scaling salts in solution for a certain length of time as the juice becomes progressively more concentrated and then would let them loose at some point, say in one of the final evaporator bodies or pans, and develop excessively heavy deposits at that point. The above figures indicate that this did not occur in the evaporators. Nyssa and Nampa report no evidence of increased scaling in the pans.

As for economic justification for this treatment, it is only possible to balance the cost of the alginate treatment against the saving in boiling out chemicals. No exact evaluation can be placed on the increased life of the evaporators or the reduced loss of tonnage during boiling out or the increased tonnage or brix due to averagely cleaner evaporators.

The following reduction in boiling out chemicals is calculated at Nyssa based upon the 1948-49 tonnage and the actual boiling chemicals listed by Nyssa as being used on that body. This was the saving in boiling out chemicals due to both lower lime salts and use of sodium alginate. Half of this total was found to be attributable to sodium alginate treatment.

Table 6.

Effect	Calculated	Saving			
	Reduction in Bodies Boiled	Drums Caustic	Sacks Soda Ash	Carboys Acid	Gallons Formaldehyde
1	4.59	4.59	55.08	68.85	68.85
2	8.31	8.31	99.72	116.34	66.48
3	6.19	6.19	49.52	49.52	24.76
4	1.31	1.31	10.48	7.86	3.93
5	3.13	3.13	25.04	18.78	9.39
Total		23.53	239.84	261.35	173.41

Total savings in dollars = $2,746.70
Saving credited to Sodium Alginate = $1,373.70

The cost of the sodium alginate treatment for the 156-day campaign at Nyssa was $2,246.40. On the basis of chemical costs above the treatment shows a deficit of $872.70. There are, of course, other items of cost to consider most of which are intangible and difficult to pin down. There are the benefits of average cleaner evaporators with the resulting increased evaporator capacity, the lessened chemical attack on the evaporators during acid boiling, and lessened loss of slicing capacity during boiling out.

There is no way to figure, on the Nyssa trial, the savings from less corrosion of evaporators or less tonnage sliced during boiling out. On the effect of average cleaner evaporators, however, we do have an indication of some benefit. For the 1948-49 campaign Nyssa sliced an average of eighty tons of beets more per day than for the 1947-48 campaign, and at a two point higher draft. In addition, the sugar in the beet was 0.53% lower in 1948-49 which resulted in 1.1 brix lower juice to evaporators. Under equal conditions this would have been expected to result in a lower brix of thick juice. Contrary to this, however, the brix of thick juice in 1948-49 was 1.5 higher than for 1947-48 (63.3 and 64.8 brix respectively). This difference in brix represents 3.66 pounds less water in thick juice per one hundred pounds of solids which must be evaporated single effect in the pans. At Nyssa's evaporator ratio of 2.15 to 1.0 this would represent a steam saving of 1.96 pounds of steam per one hundred pounds of dissolved solids introduced. This would have represented a saving of approximately 22,000 pounds of steam per 24 hours. This saving, if correct, would easily put the sodium alginate treatment on the profit side. It was felt that the picture was sufficiently attractive to expand the trial to both the Nyssa and Nampa factories during the current campaign.

Three Years Experience With Commercial Organic Scale Inhibitors

ROBERT S. GADDIE[1]

In maintaining the efficiency of the evaporators in the sugar factory, the most important factor and the one least subject to control is the fouling of heat transfer surfaces by the formation of scale. Even the best purified and clarified juices in most houses contain salts which precipitate out on the heating surfaces as the juice is concentrated. As these insolubles collect on the tubes, the capacity of the evaporators for any given load decreases, until a point is reached where one or more bodies must be taken out of service and boiled out. The length of run between successive boil-outs varies from as little as three or four days to a full campaign, depending on the composition of the evaporator influent and other local conditions.

From a fuel standpoint alone, scaling of the evaporator heating surfaces is obviously expensive. Added to this is the cost of cleaning chemicals, corrosion of equipment by these chemicals, and lost time and cost of extra labor during boil-outs. There is, therefore, great economic justification for any chemical or combination of chemicals which will prevent or even inhibit such scale formation. However, to expect any treatment to answer all of the problems created by a variety of conditions and juices is foolish. Even in the same set of evaporators, the chemical equilibria are constantly changing as the concentrations of the various substances in the juice increase or decrease during operation. Coupled with the complex physical chemistry of the scaleforming components in the juice is the utter lack of a reliable method of evaluating various scale inhibitors in the laboratory. The only means, therefore, by which the efficiency of evaporator scale inhibitors can at present be estimated is by a full scale factory trial. Even then, economic justification for any treatment must be established independently for each factory, in accordance with its own conditions.

In the last three years, considerable success has been reported in the control of evaporator scale in the cane industry by a combination of polyphosphates and various sequestering colloids. In view of this, during the latter half of the 1947 campaign, two such treatments were tried: one at the Idaho Falls plant, and one at the Garland plant. Both of these factories are Steffen houses and both have severe scaling problems.

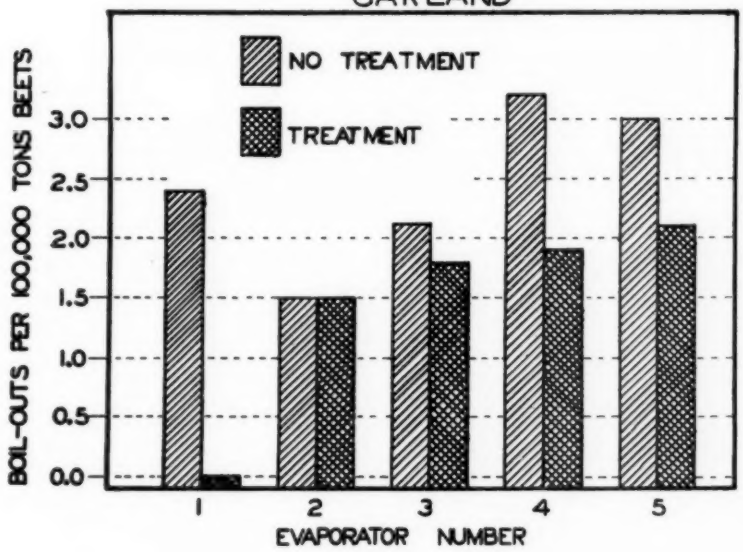
The compound used at Idaho Falls was tetra-phospho glucosate (T.P.G.) manufactured by D. W. Haering Co. The T.P.G. was dissolved in hot water and the solution added continuously to the thin juice in the evaporator supply tank ahead of the evaporator preheaters at the rate of 12 p.p.m. of the original chemical based on thin juice. For 27 days of the Idaho Falls campaign, beta glucoside was also added at the rate of 6 p.p.m. based on

[1] General Chemist, Utah-Idaho Sugar Company.

thin juice, but there was no noticeable difference in the rate of scale deposition during this addition, so it was discontinued.

The treatment at Garland consisted of a colloid or mixture of colloids extracted from seaweed and containing an equivalent of 12% sodium alginate. Coupled with this was added a sodium tri-poly-phosphate compound. These materials are termed "Evaporator Concentrate" and "APA-M," respectively, by the manufacturer, E. F. Drew Co. A 50-50 mixture by weight of the two was dissolved in water, strained through cheesecloth, and fed into the evaporator supply tank at the rate of 8 p.p.m. based on thin juice.

FIGURE 1
GARLAND



Both the tetra-phospho-glucosate and the Evaporator Concentrate are what are known as "protective colloids." They tend to prevent the formation of anything but a colloidal precipitate. Protective colloids will exhibit this property when in their absence a crystalline precipitate would be formed. This effect is due to the formation of a stabilizing envelope about the particles, which results in the formation of suspensoids preventing the precipitation as an adherent scale.

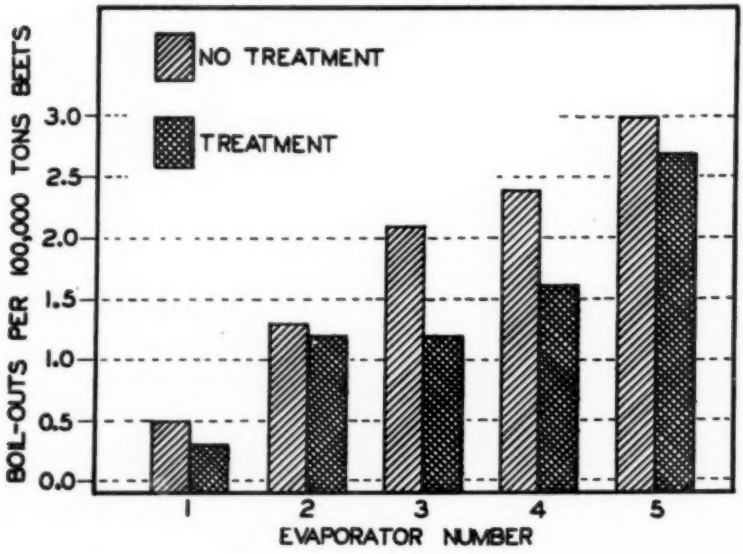
The role of the phosphate is undoubtedly twofold. Polyphosphates, while they remain as such, form soluble compounds with scale-forming elements, which apparently have the property of keeping far more than an equivalent amount of scale former from precipitating. In addition to this, the phosphate undoubtedly acts as a peptizing agent for the colloid. How-

ever, these polyphosphates must be used judiciously, because they have the property of reverting to orthophosphate in solutoin, reversion being slow at ordinary temperatures, but much accelerated by rise in temperature. These orthophosphates form insoluble calcium and magnesium orthophosphates which are prone to precipitate in the white pan, with resultant high turbidity of the final granulated.

Results of 1947 Trials

During the 1947 trial, both Idaho Falls and Garland ran the first part of campaign without treatment and the last half with treatment. The T.P.G.

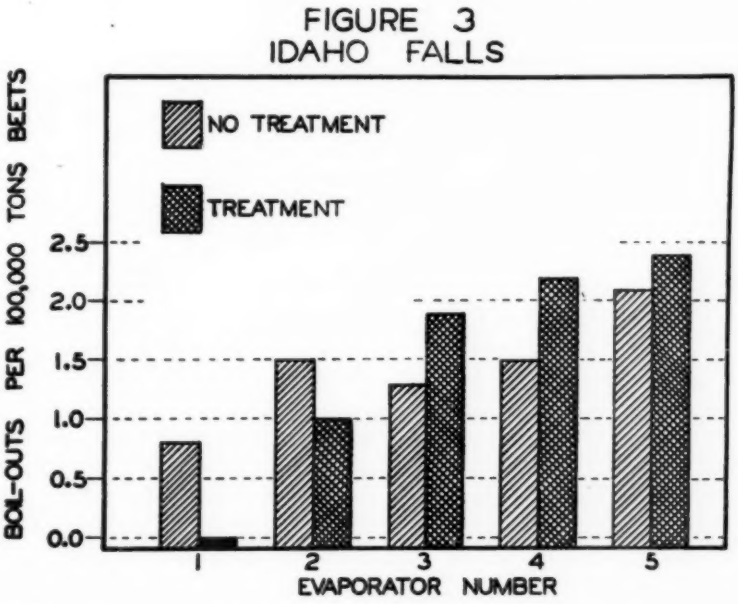
FIGURE 2
TOPPENISH



treatment at Idaho Falls did not decrease the number of evaporators boiled out. On the other hand, the algin treatment at Garland effected a 45% decrease in boiling out requirements. At both plants, however, one significant fact was observed. Both treatments completely inhibited scale formation in the thin juice heaters and in No. 1 effect. Only very light scale deposition was observed in No. 2, but the colloid seemed to let go of the scale in No. 3 where the deposition was heavier than in No. 4. This was evidenced by the fact that No. 3 was boiled more times than No. 4, yet when inspected at the end of campaign the deposit was heavier in No. 3. This delayed precipitation is a phenomenon which has often been observed in working with protective colloids.

From previous experience in operating sugar factories, we are all aware that conclusions on any experiment such as the above when based on a one-year trial are very apt to be faulty and misleading. However, results obtained this first year were encouraging enough to warrant continuation of the experiment. So, in the campaigns of 1948 and 1949 the algin-APA-M treatment was added at Toppenish. T.P.G. was continued at Idaho Falls, and Garland continued using the algin.

During these two campaigns, two changes were made in the treatment. First, because of the delayed precipitation effect in No. 3 evaporator, the



50-50 mixture of algin and APA-M was split; two-thirds of the treatment was fed to the evaporator supply tank, and one-third added directly to No. 3 evaporator. Second, the dosage of the Drew treatment was increased to 10 p.p.m. based on thin juice.

The results for the three-year treatment at Garland and Idaho Falls and for two years at Toppenish are shown in Table 1. These results are compared with the four previous years at the respective plants when no treatment was used.

Here again it may be noted that T.P.G. did not reduce the total number of boil-outs at Idaho Falls, but that the algin gave a substantial reduction at Garland and Toppenish. However, while T.P.G. did not decrease the total boilouts, the evaporator heating surfaces were kept in a

very much cleaner condition than before. Even more important than this was the fact that since the treatment was started it has been unnecessary to clean No. 1, and only about two-thirds as many cleanings have been necessary on No. 2.

The various necessary boil-outs for the individual bodies during the two periods shown in Table 1 are pictured graphically in Figs. 1, 2, and 3.

The cost of boiling out an evaporator has been estimated by the superintendents at these three plants, and these estimates will, of course, vary with the cleaning chemicals used, the thickness of the scale, and the body which is being cleaned. On the average, however, cost of cleaning chemicals

TABLE 1

FACTORY	TREATMENT	AVERAGE TONS BEETS PER YEAR	BOIL-OUTS PER 100,000 TONS BEETS
IDAHO FALLS	NONE	120029	7.2
	T.P.G	142911	7.5
GARLAND	NONE	125842	12.2
	ALGIN	123166	7.3
TOPPENISH	NONE	281932	9.3
	ALGIN	285524	7.0

is very close to $115.00 per evaporator. In addition to this cost, and particularly where automatic evaporator controls are being used, at least 8 man-hours of labor must be charged. This gives a total material and labor cost of approximately $125.00 per evaporator boiled out. Other costs, perhaps more important, but difficult to evaluate, are corrosion effects, increased steam consumption, and loss of capacity. These costs are, of course, very much greater when frequent boilings of Nos. 1 and 2 are necessary. Steam consumption is increased, regardless of which body is boiled out. However, sufficient steam is available to boil out Nos. 3, 4, and 5 without capacity loss. This is not true of Nos. 1 and 2. When they are boiled out, loss of capacity usually results.

The combination of algin and phosphate costs 26½ cents per pound. At 8 p.p.m. based on thin juice, the cost of evaporator treatment at Garland is $594 per 100,000 tons of beets, and at Toppenish is $510 per 100,000 tons of beets. Considering only the cost of materials and labor for boiling

out, Garland has more than saved the expense of the treatment, while Toppenish has saved about 56% of the expense.

In addition to the savings which have already been mentioned, we have observed that in those factories using the treatment evaporators were kept constantly cleaner, resulting in lower back-pressures and higher evaporator and boiler efficiencies.

Conclusions

Treatment of evaporator influent with an algin colloid-phosphate combination at two beet sugar plants over a period of three years has definitely decreased scaling of the evaporator heating surfaces, when compared with four years previous operation.

Treatment of evaporator influent with tetra-phospho-glucosate at another plant for a three-year period did not decrease the total amount of boil-outs, but the scale was nearly all deposited in evaporators 3, 4, and 5.

Algin-Phosphate Treatment

A treatment of 8 p.p.m. based on thin juice seems to be about the optimum dosage. Less than this produces less effect. Ten p.p.m. did not result in a comparable decrease in scale deposition.

Splitting the addition, two-thirds to the evaporator influent and one-third to No. 3 body, did not decrease the heavy deposition in No. 3. In fact, the entire dosage fed to the evaporator supply tank seemed to be somewhat more effective.

The addition of the chemical must be steady and continuous throughout the entire campaign.

Evaporator heating surfaces must be kept relatively clean. Once the heating surfaces have become fouled, thorough cleaning by one of the conventional methods is essential before the treatment can again be fully effective.

It was necessary to discontinue the treatment for short periods while processing spoiled beets. The colloid increased the foaming characteristics of an already foamy juice to a point where it could not be handled in the evaporators.

Poor filtration of the thin juice which leaves in suspension a small amount of second carbonation mud uses up the colloid immediately, and its beneficial effects are noticeably absent.

No abnormal effects were detected either in the white pans or in the final granulated. Apparently the treating chemicals and their occluded salts remain in suspension throughout and are eliminated in the molasses.

Trials of one and two years duration at two of our other factories have not shown beneficial results. This emphasizes the fact that economic justification for a treatment of this type must be established independently for each factory, in accordance with its own conditions.

The Relationship of Sugar Moisture to Relative Humidity

J. E. MAUDRU[1] AND T. E. PAXSON[2]

The maintenance of proper relative humidity in sugar storage warehouses and bulk storage bins is of great importance not only from the standpoint of eliminating hard and lumpy sugar but also from a bag breakage standpoint.

The sugar crystal, possibly slightly hydroscopic in its pure form, contains minute amounts of ash and a thin coating of even more impurities on its surface which causes it to be even more hydroscopic.

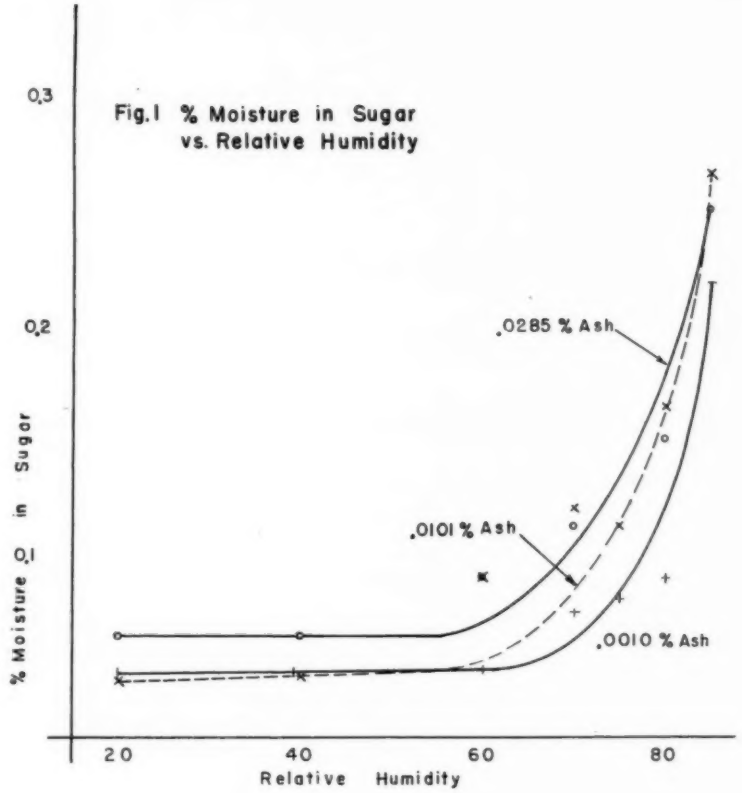
Changes in relative humidity cause sugar to absorb or release moisture to maintain equilibrium. An increase in relative humidity of the air surrounding the sugar releases moisture. This moisture dissolves a small amount of sugar from the crystal faces until a saturated solution of minute thickness occurs on the crystal face. This condition is not objectionable except at high humidities where the sugar becomes crawly.

Decreasing humidity causes hard sugar by reversing the above series of events. Water evaporates from the crystal faces and recrystallizes sugar on them. The point of contact of two touching crystals enlarges and fuses so that the crystals stick together. Each time the humidity is lowered the foregoing process is repeated so that finally the sugar becomes a hard mass.

Figure 1 shows the relationship of moisture in sugar to relative humidity of surrounding air. Conditions for sugar of low (.0010%) ash, medium (.0101%), and high (.0285%) ash are shown. The high ash sugar starts gaining moisture at something more than 40% humidity while the low ash sugar maintains a constant mositure content to more than 60%. All three sugars increase rapidly in moisture above 75% and at 85% humidity start to liquefy. This data was collected by determining moisture on small samples of sugar after they had been allowed to reach equilibrium in a dessicator in which air of controlled humidity was present. Humidity was controlled by the method of Stokes & Robinson[3] in which sulfuric acid of various concentrations was placed in the bottom of the dessicator. Large quantities of the acid solution and small samples of sugar were employed so that changes in moisture of the sugar would not change appreciably the concentration of acid. Samples remained in the dessicator 4 days to assure equilibrium.

Relative Humidity	% Anhydrous H_2SO_4 by weight
20	57.76
40	47.71
60	38.35
70	33.09
75	30.14
80	26.79
85	22.88

[1] General Chemist, Holly Sugar Corp., Colo. Springs, Colo.
[2] Chief Chemist, Holly Sugar Corp., Delta, Colo.
[3] Stokes, R. H., & Robinson, Ind. Eng. Chem. 41, 2013 (1949)



The straight line graph on Figure 2 shows moisture content of paper from a natural craft 5 ply, 250-lb. basis, 100-lb. paper bag again plotted against relative humidity. We have it on good authority that paper becomes dangerously brittle, causing excessive breakage below 7% moisture, which corresponds to about 40% relative humidity. We must then store sugar between 40 and 60% relative humidity to minimize breakage due to paper brittleness on the one hand and prevent hard sugar on the other, by drying out after the sugar leaves the warehouse.

The western climate is characterized by great changes in humidity. The humidity on a cold winter day may be as low as 10%. If the outside temperature is —20° F. and if the air is heated in the warehouse to +50° F. the relative humidity becomes almost 0. If later a warm thaw occurs, the outside temperature may become +40° F. with 60% humidity. Upon being heated to 50° F. the humidity is only reduced to 40%. Thus, the humidity varies from almost 0% to 40% without changing the warehouse temperature.

Warehouses, then, require controlled humidification and temperatures should be no higher than necessary.

Another source of hard sugar in connection with bin sugar occurs, during cold weather, by bringing the bulk sugar into a humid warehouse when the sugar is below the dew point of the warehouse air. The sugar absorbs moisture and later upon releasing the moisture to reach equilibrium it cakes and becomes hard.

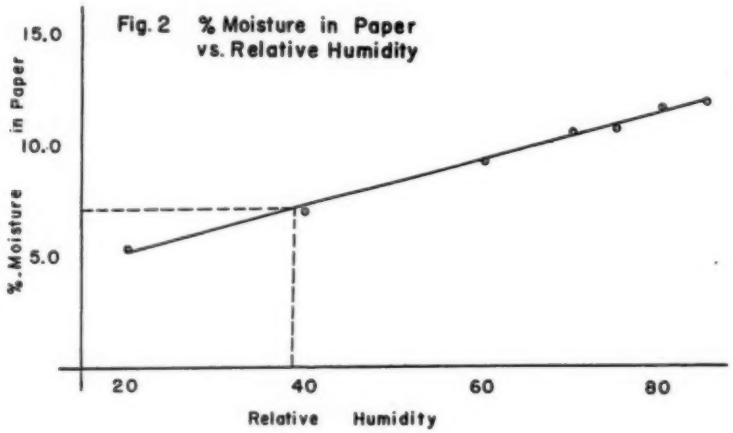


Fig. 2 % Moisture in Paper vs. Relative Humidity

In summary, warehouse air should be controlled both as to temperature and humidity. Relative humidities between 40 and 60% minimize breakage and prevent hard sugar. High ash sugars are more hydroscopic than sugars of lower ash content.

Additional investigation should be made on the factors which affect the strength of paper with the thought that a paper might be developed which is not so sensitive to low relative humidity.

Delayed Sucrose Analysis of Pulped Beet Samples

C. E. CORMANY[1]

The deep freezing of pulped sugar beet samples for later sucrose analysis appears promising for field plot work. Preliminary tests in 1947 and 1948 indicated that very little change in sucrose content took place in samples frozen shortly after pulping. Delayed analysis, provided it does not change the relative ranking of varieties, certainly may be desirable in plot harvesting in cases in which equipment and qualified manpower are limited and the harvest season short.

Methods

A practical test involving the statistical analysis of sucrose contents of a variety test was conducted in 1949. This consisted of 25 varieties replicated

Table 1.—Sucrose Analysis on Pulped Beet Samples After Various Periods in Frozen Storage.

	Sucrose Analysis in Percentage									
Variety No.	Original Analysis	After 3 wks. storage	Change over last test	After 6 wks. storage	Change over last test	After 9 wks. storage	Change over last test	After 12 wks. storage	Change over last test	Total Increase
1	16.38	16.52	.14	16.74	.22	16.68	—.06	16.65	—.03	.27
2	16.74	16.94	.20	17.03	.09	17.08	.05	17.07	—.01	.33
3	16.76	16.87	.11	17.09	.22	17.12	.03	17.10	—.02	.34
4	17.81	18.01	.20	18.14	.13	18.16	.02	18.19	.03	.38
5	17.48	17.72	.24	17.83	.11	17.90	.07	17.88	—.02	.40
6	16.62	16.83	.21	16.96	.13	16.98	.02	16.95	—.03	.33
7	16.95	17.21	.26	17.24	.03	17.21	—.03	17.27	.06	.32
8	16.34	16.70	.36	16.79	.09	16.76	—.03	16.80	.04	.46
9	16.65	16.89	.24	17.02	.13	17.01	—.01	17.01	....	.36
10	16.91	17.08	.17	17.18	.10	17.23	.05	17.24	.01	.33
11	16.08	16.23	.15	16.46	.23	16.37	—.09	16.40	.03	.32
12	16.27	16.45	.18	16.62	.17	16.49	—.13	16.67	.18	.40
13	16.64	16.91	.27	17.03	.12	17.05	.02	16.92	—.13	.28
14	17.26	17.50	.24	17.56	.06	17.65	.09	17.51	—.14	.25
15	17.44	17.60	.16	17.65	.05	17.68	.03	17.76	.08	.32
16	16.51	16.74	.23	16.82	.08	16.88	.06	16.95	.07	.44
17	16.58	16.91	.33	16.92	.01	16.89	—.03	16.95	.06	.37
18	17.18	17.36	.18	17.41	.05	17.45	.04	17.42	—.03	.24
19	16.64	16.83	.19	16.96	.13	16.94	—.02	17.00	.06	.36
20	15.82	15.98	.16	16.07	.09	16.06	—.01	16.18	.12	.36
21	16.72	16.95	.23	17.08	.13	17.01	—.07	17.08	.07	.36
22	18.40	18.58	.18	18.60	.02	18.60	....	18.70	.12	.30
23	16.38	16.72	.34	16.76	.04	16.75	—.01	16.72	—.03	.34
24	16.33	16.56	.23	16.66	.10	16.70	.04	16.72	.02	.39
25	16.28	16.48	.20	16.63	.15	16.59	—.04	16.68	.09	.40
Gen. Mean	16.77	16.98	.21	17.09	.11	17.09	....	17.11	.02	.34
LSD (19:1)	.39	.39		.41		.41		.40		
Calc. F Value	19.4755[1]	20.5673[1]		16.8133[1]		17.5908[1]		18.9726[1]		

[1] Exceeds the 1% Point : 2.06

[1] Chief Agronomist, Holly Sugar Corp., Sheridan, Wyoming.

six times each, or a total of 150 plots. Two pulped samples were taken for each plot and placed into containers when making the original sucrose analysis at harvest. No preservatives of any kind were added. These were taken to deep freeze within one and one-half hours after pulping. Samples were stored at —15° F. At intervals of three, six, nine and twelve weeks 300 samples were removed and thawed in a dry heating chamber with a temperature of 110° F. Thawing required from thirty to fifty minutes. Duplicate samples were weighed from each container as soon as the lid was removed. Analysis followed.

Results

A slight increase in sucrose readings was evident at the end of the third and sixth week. Subsequent readings remained practically the same as the six weeks level. The largest average raise, .21 percent, occurred at the three-week period. To this was added .11 percent increase for the six-weeks period, none for the nine-week period, and .02 percent for the twelve-week period. The total average raise was .34 percent. The least average raise of any variety at the end of the twelve-week period was .24 percent, the largest .46 percent (See Table 1). Statistically, the data for each date are very similar. Rankings for 8 of the plots were identical at the three- and six-weeks periods, fifteen at the nine-week period and thirteen at the twelve-week period.

No differences in the final product were noted in 1947 in comparing tin and paper containers.

In the 1949 tests both tin and paper containers were compared for additional data. Two complete replications were stored in metal containers and four complete replications in waxed paper ice cream cups. The metal containers were much more satisfactory in every respect. A metal container with a tight fitting lid should be used. The final results showed a much greater change in sucrose content in the paper cups (See Table 2).

Table 2.—Effect of Type of Container on Final Sucrose Content of Stored Pulped Beet Samples.

Type of Container	Replication No.	Sucrose Analysis in Percent				
		Original	3 Wk.	6 Wk.	9 Wk.	12 Wk.
Metal	I	16.37	16.49	16.57	16.51	16.53
Metal	IV	16.78	16.93	17.02	16.99	16.90
Ave. of Metal		16.58	16.71	16.80	16.75	16.71
Paper	II	16.71	17.02	17.06	17.08	17.12
Paper	III	16.86	17.05	17.22	17.24	17.24
Paper	V	16.90	17.18	17.32	17.38	17.47
Paper	VI	17.00	17.22	17.35	17.35	17.41
Ave. of Paper		16.87	17.12	17.24	17.26	17.31

Summary

The deep freezing of pulped beet samples for later sucrose analyses appears promising for field plot work. It may also have other applications. Data analyzed statistically covering 25 varieties of sugar beets, with six replications each, showed practically identical results for pulp stored three, six, nine and twelve weeks. A slight increase in the sucrose content was noted in the stored samples but the variation in L.S.D. (19:1) increased only slightly from .39 to .41 percent, indicating that the sucrose data after deep freeze storage is quite reliable. Metal containers gave much better results than waxed paper and were more satisfactory in handling.

Recovery of Waste Ammonia in Ion Exchange Operation

ROBERT H. COTTON, GUY RORABAUGH AND W. A. HARRIS[1]

In the commercial application of ion exchange to the purification of beet sugar juices as practiced at the Hardin, Montana, plant, ammonia is used to regenerate the anion column. The amount of ammonia used per cycle ranges from 400 pounds to 600 pounds. Of this amount approximately 250 to 300 pounds is fresh make-up and the remainder is recycled regenerant. There are 412 cubic feet of Duolite A-2 resin in each anion column. The fresh ammonia requirements are approximately 5 to 7 pounds per ton of beets. This figure rises as the purity of the beets drops. Ammonia at Hardin

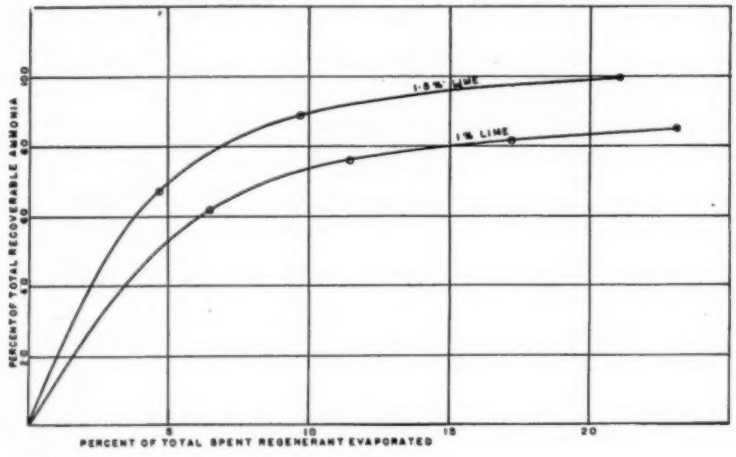


Figure 1.

is very expensive in part because of freight. A study was conducted there with the objective of reducing ammonia requirements in ion exchange by recovery of ammonia through distillation of spent anion regenerant.

In the present system of regeneration at Hardin, after backwashing, a solution of ammonia from 2 to 4% is passed through the column. The effluent from this column goes first to the spent regenerant tank. The flow continues until a large proportion of the impurities held by the anion column has been displaced. At this time the concentration of ammonia in the spent anion regenerant has become relatively high and the flow is diverted to the ammonia make-up tank. This provides a solution relatively rich in ammonia and fairly low in impurities into which is later added fresh

[1] Holly Sugar Corporation, Colorado Springs, Colorado.

ammonia for regeneration of the next anion column. Once these requirements have been met the flow is again diverted to the spent anion tank. The spent anion tank and the spent cation tank, which contains acid from regenerating the cation column, are dumped simultaneously to the sewer in order that much of the sulfuric acid in the spent cation regenerant can be neutralized by the ammonia.

Preliminary studies were made to determine the approximate concentration and amount of ammonia which could be freed by distillation from the spent anion regenerant. Several results were obtained:

(1) A relatively small proportion of the total volume of spent anion regenerant had to be distilled in order to free a large proportion of the distillable ammonia.

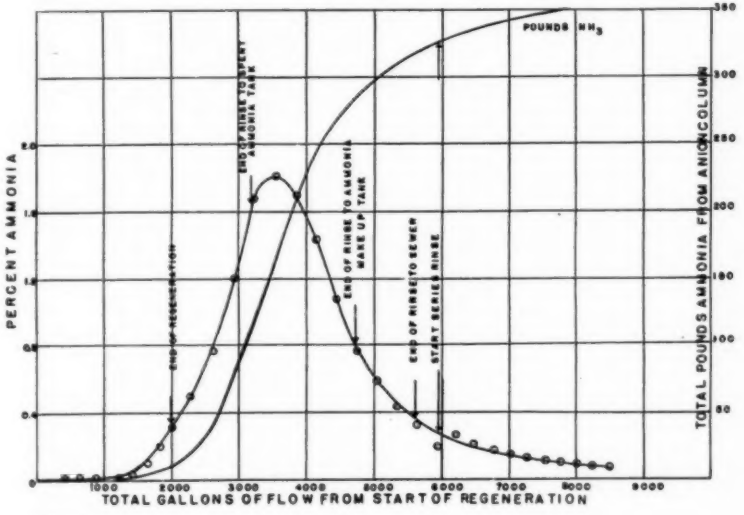

PERCENT AMMONIA
TOTAL POUNDS AMMONIA FROM ANION COLUMN
POUNDS NH_3
END OF REGENERATION
END OF RINSE TO SPENT AMMONIA TANK
END OF RINSE TO AMMONIA MAKE UP TANK
END OF RINSE TO SEWER
START SERIES RINSE
TOTAL GALLONS OF FLOW FROM START OF REGENERATION

Figure 2.

(2) It was found that if one distilled ammonia from the spent anion regenerant there would be frequently, but not always, a white precipitate which would foul the surface of the condenser.

(3) It was next determined that the use of lime added to the spent anion regenerant allowed one to recover more ammonia than if no lime was added; it allowed one to recover ammonia at a faster rate; it prevented the formation of the white scale on the ammonia condenser.

The amount of ammonia in the spent regenerant was found to vary between 0.5 to 1.0% distillable ammonia. Figure 1 presents results for

experiments in which two levels of lime were added to the spent regenerant followed by distillation. It will be seen that if 1% lime is added to spent regenerant that by evaporating 10% of the total volume of liquid one can recover approximately 75% of the total distillable ammonia, and by distilling 20% of the total volume one can recover approximately 82% of the total distillable ammonia. When one adds 1.5% lime, he can recover 90% of the total distillable ammonia by distilling only 10% of the spent re-

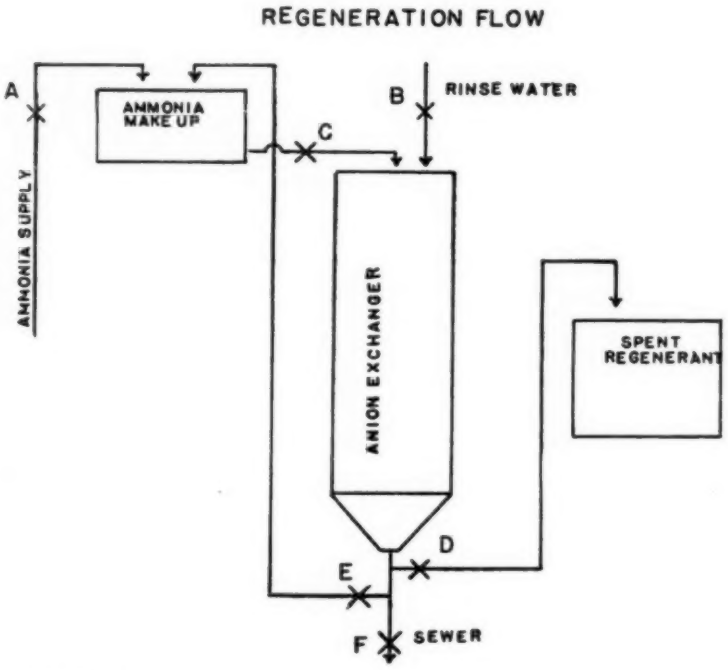


Figure 3.

generant, and finally if one distills 15% of the total volume he can recover 97% of the total distillable ammonia when 1.5% lime is added. In order to obtain the last remaining 3% of the total distillable ammonia one would have to distill another 7½% of the water. Not shown in Figure 1 are data obtained where 2% and 3% lime on spent regenerant were added. The curves were very slightly steeper at 5% evaporation but practically identical at 10 and 15% evaporation with the curve obtained with 1.5% lime. It was interesting to note that the condensate obtained by distillation of spent anion regenerant had almost exactly the right concentration of ammonia for regenerating the anion column. It should also be pointed out that the

results were substantially identical whether the distillation was carried out by heating the regenerant in a flask or by injecting live steam into the solution. The latter technique was studied because in commercial practice we would expect difficulty from scaling of heat transfer surfaces.

Figure 2 shows concentrations of distillable ammonia plotted against gallons of flow from the start of the regeneration cycle at the Hardin plant.

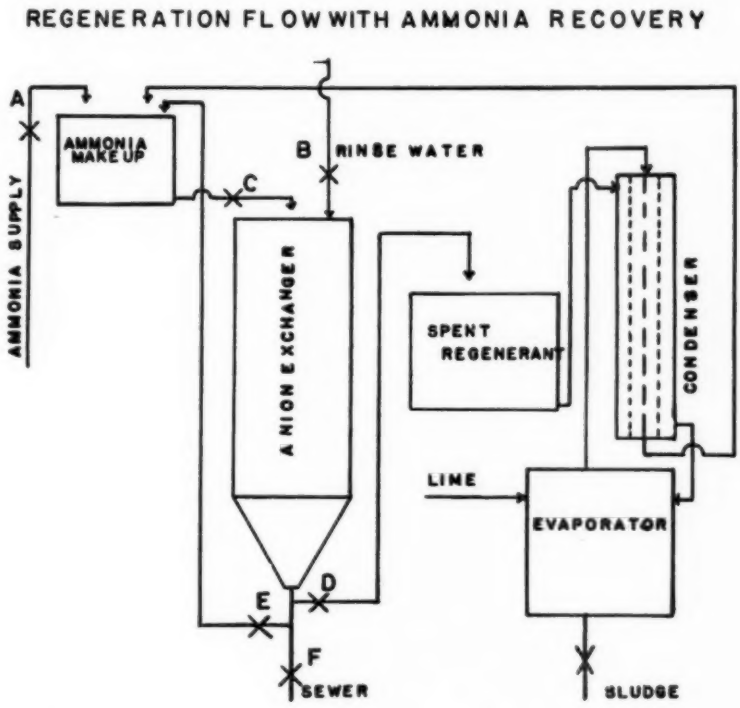


Figure 4.

The top curve shows the cumulative total pounds of ammonia from anion column from the start of the cycle. It shows the various operations in the regeneration cycle. From this graph one can determine what the amounts and concentrations of ammonia would be if one saved only spent regenerant having 0.2% ammonia or greater. This was done, neglecting that amount of ammonia which goes to the ammonia make-up tank since the present anion exchange system already reuses this ammonia profitably. This cut, between 3,240 and 4,740 gallons, is used to dissolve fresh ammonia for regeneration. In the first study made, it was found that 260 pounds of fresh

ammonia were used on each cycle and that one could recover by distillation 138 pounds of ammonia from a selected cut of the spent regenerant obtained by the flow volume 1,440 to 3,240 and 4,740 to 5,640. This represents a reduction of approximately 50% of the fresh make-up ammonia requirements. From Figure 2 it was calculated that the percentage ammonia should be 0.75%. A subsequent series of determinations gave a calculated average concentration of 0.81% recoverable ammonia for the same portions of the cycle. A large composite sample (45 gallons), representing these portions and made from several cycles, showed an actual concentration of 0.83% recoverable ammonia. The regenerant solution in these cases was stronger than had been used previously. The recovery would be effected by the use of 1.5% lime and 15% distillation. Economic analyses indicate that this would be a very profitable operation on a plant scale. One of the principal advantages of the system is simplicity. For example, in contrast to many ammonia recovery systems no complicated equipment, compressors, etc., are needed. One simply distills the ammonia, the vapors are condensed on a water cooled condenser and are reused. The water cooled condenser can operate as a preheater for the feed. Figures 3 and 4 show the old system of regeneration and the new system modified for recovery of ammonia. The process is covered by a patent application.

Ion Exchange Behavior on Two-Boiling System at Layton Sugar Company

DONALD M. STROMQUIST[1]

The 1949 campaign at the Layton Sugar company was a short but successful campaign and its success was due in part to the method of operation and in part to the deionization equipment installed there in 1947 by the Illinois Water Treatment Co. This equipment consists of four pairs of ion-exchange units which are interconnected by a common system of four, five, and six-inch piping which conveys juice, water and regenerants in their proper order to the cation and anion cells. The cation cell is 10 feet by 14 feet and holds approximately 625 cubic feet of cation resin; the anion cell is 10 feet by 11 feet and now holds approximately 412 cubic feet of anion resin. This resin balance permits treatment of 1,300 tons of beets per day with each unit operating on an average one and three-quarter hour cycle. The units treat cooled second carbonation beet juice and then pass the resultant deionized high purity juice back into the process at the evaporation station. Fluid flow is controlled manually by Hills-McCanna saunders patent valves. The regenerant tanks which are common to the four units have the proper amounts of chemicals metered into them by automatic controls. Bulk storage tanks for concentrated sulfuric acid, 20% caustic, and 20% ammonium hydroxide are provided. All tanks, as well as necessary piping, are rubber lined.

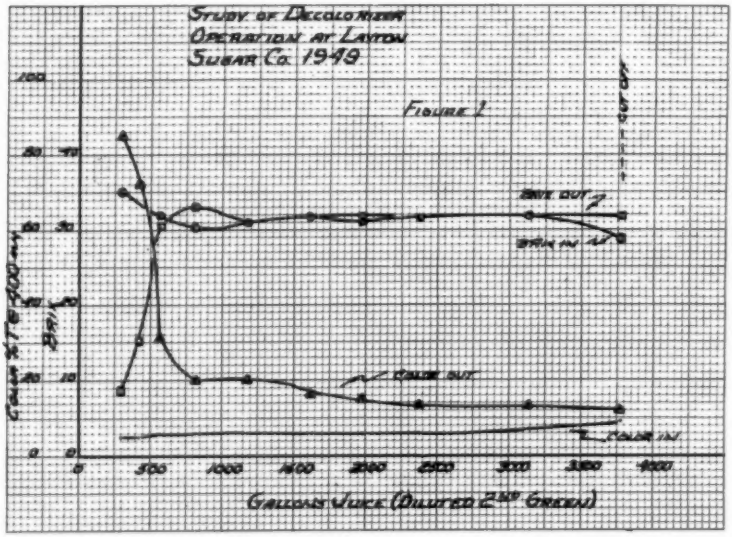
In a normal deionization operation on beet sugar juices such as the 1948 operation at Layton, the order of cycle is—backwash, regeneration, rinse, service, sweetening off and then a repetition. In 1947 and 1948, we treated the second carbonation juice in its entirety, and in instances experimentally returned various diluted greens without too much success because of excessive color build-up. Because of the resulting more intensely colored influent juice, the ion exchange units would operate at a lower efficiency and would slip color bodies back into the process. Thus it was evident that, in order to obtain ultimate extraction, some system of color removal from sugar juices was necessary. A multiple boiling system was not the answer either because repeated contact of the unbuffered juices with the heating surfaces intensifies the juice colors even more. This of course makes it increasingly difficult to obtain a third white sugar strike.

Table 1.—Regenerants Used in 1948 and 1949 in Pounds per Ton of Beets.

Regenerant	1948	1949
Sulfuric Acid	12.94	17.75
Ammonia	5.68	7.00
Caustic Soda	2.45	5.05
Cost per Ton of Beets	47.98c	71.9c

[1] Research Chemical Engineer, Illinois Water Treatment Co.

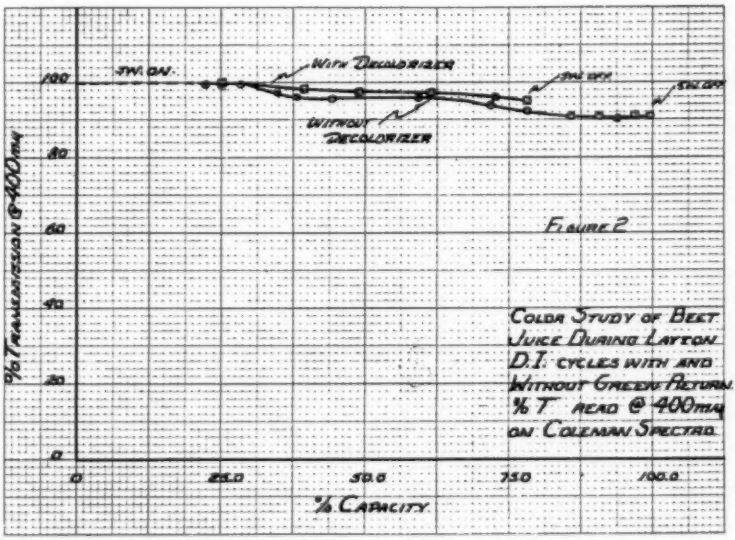
Experiences during the inter campaign period in color removal from deionized molasses for the production of an edible syrup gave us the answer to the proper mode of operation. For the de-colorization we employed a regenerable granular phenolic resin that when properly applied was quite efficient in removing color bodies from sugar solutions. During campaign, this material was utilized in three 42-inch by 10-feet tanks which were designed similar to deionizer reactor tanks, and were handled in a like manner, i.e., one on stream while the others were being regenerated. The material from which we removed color bodies was the green syrup from



the second white pan. We obtained two white strikes of sugar from our deionized standard syrup and then decolorized the diluted second green by percolating it through the granular regenerated decolorizer. A dilute solution of caustic soda was used as the regenerant. After color removal, the green syrup was introduced into the process again at the beet end, where practically all invert was destroyed by means of carbonation. The brix of the material treated was cut from about 70 to 35 with thin juice, and each decolorizer unit performed for approximately six hours at flows ranging from 25 to 30 gallons per minute. By utilizing thin juice for the necessary reduction in brix, we avoided adding any excess water to the process other than the dilution inherent to sweetening on and off the decolorizer units. Color removal is actually greater than the 7 percent indicated at the end of the run because it is a log rather than linear relationship.

The second green syrup contains a concentration of all the solids which have once slipped by the ion exchangers plus an accumulation of color bodies and caramels which are the result of continued contact of a sugar bearing

solution with heating surfaces. The anions contained in this green return were experimentally determined by decationization of a 35 brix solution and were found to be in excess of 200 grains per gallon ($CaCO_3$ equivalent). Most of the acids thus determined titrated in the pH range of 3.5 to 4.0, proving that they were for the most part weak acids, which are very difficult to remove in any excess by means of a weak base anion exchanger such as that employed at Layton. A flow of 30 gallons per minute of such a green syrup is equivalent to at least 60 gallons per minute of thin juice, which would account for more than 15% of the capacity of each ion exchange



unit. By taking the nature of the acids into consideration, that is, their low dissociation, the return would take up 20% of the resin capacity and in particular the capacity of the anion exchanger.

Even though the individual beet juice cycle is shortened materially by green recirculation, very little difference is noticed in color removal from thin juice incidental to ion exchange because color concentration is of the same order as that in second carbonation juice without decolorized green. The finished juice in either case is colorless to the naked eye and proved of excellent quality when color readings were observed on a spectrophotometer. Similar readings were observed throughout the campaign and none was observed below 90% transmittance.

Of the two resins necessary for deionization, that is, cation and anion, it is evident that the cationic resin is quite stable and the anion resin is subject to deterioration if proper care of the resin is not observed, and particularly so in sugar work. In the deionization of beet sugar juices we

have many cycles per day, a wide variety of dissolved solids in the juice other than sugar and in general quite severe conditions not usually found in other applications. In spite of this, the cation resin at Layton has been used for three campaigns with little or no deterioration. The anion resin has been used for two admittedly short campaigns with quite favorable results. The exhaustant used was a mixture of mineral and organic acids, the concentration of which was 100 grains per gallons ($CaCO_3$ equivalent) and the nature of which simulates the beet juice treated. It is interesting to note the initial reduction in capacity experienced on the new resin and the leveling off or slow loss in capacity from that point on. The anion resin has retained its hard granular texture and is still light in color, both being physical indications of a minimum loss in capacity. As this particular anion becomes damaged, it first loses its ability to absorb weak organic acids and it seems to have lost little or none of its efficiency for this adsorption. The cation resin bed depth is substantially the same, but some anion resin has been lost due to its fine nature. In our opinion it would be wise to control grain size of this material to larger than 30 or 40 mesh to minimize loss from fine particle carry over in backwash.

This year's chemical cost figures are higher than those obtained on the 1948 operation. There are several factors which contributed to the increased cost and the higher chemical consumption. These figures include the chemicals used for the three decolorizer units, as well as the pilot ion-exchange syrup plant, both of which measurably increased the caustic and acid consumption. Then, too, recirculation increased our large deionizer regenerants by some 20% because of the resulting increased solids content of the thin juice. However, these increased costs are offset by a considerable margin, because by their use we obtain an overall extraction of 96.5%.

The deionization station operated exceptionally well during the 1949 campaign and gave no trouble other than minor mechanical difficulties. For the entire campaign we averaged fifteen regenerations a day, which gave us an average hour and 36 minute run and an ample four and three quarters hours regeneration time. In considering how many regenerations we should have obtained with a 20% overload, we may take 20% of the rated thirteen daily regenerations and add it thereto and come very close to the amount we actually obtained. No difficulty was experienced with maintaining pH in the evaporators. Standard juice samples read from 30 to 40 percent transmittance at 410 mu over the entire campaign—this particular color being a very light straw yellow. Dilution figures are not available for this year's run because on occasions we were forced to split our stream on sweetening off, i.e., we pushed some juice ahead to the evaporators and some back to the second carbonation bumper tank, because of limited effluent pump capacity. This of course made our meter readings somewhat ficticious.

We also noticed that the pH of the finished juice during the deionization cycle followed a normal pattern. The intial pH generally had a value of 9.0 to 9.5 and dropped in a sloping curve to a pH of 7.0. This is favorable in that it gives little or no evidence of oxidation of the reactive groupings of the anion resin.

At the conclusion of the 1949 campaign, practically all greens were

recirculated through the ion exchange plant in order to speed up the clean-up and also to get all available sugar into the bag for remelt the following year. This permits the retention of granulated sugar rather than lower purity syrups.

After the campaign, we started the processing of two tank cars of straight house molasses as an experiment in order to determine the feasibility of making white sugar out of such a material when it could be contracted at a good price. Some difficulty was had because the dilution control was poor but indications were that such an operation would be desirable. The material at 10 brix gave us a favorable cycle and also enough water to keep the evaporators from idling. We produced a near water-white juice after the dilution difficulty and managed to sack 575 bags of white sugar. The

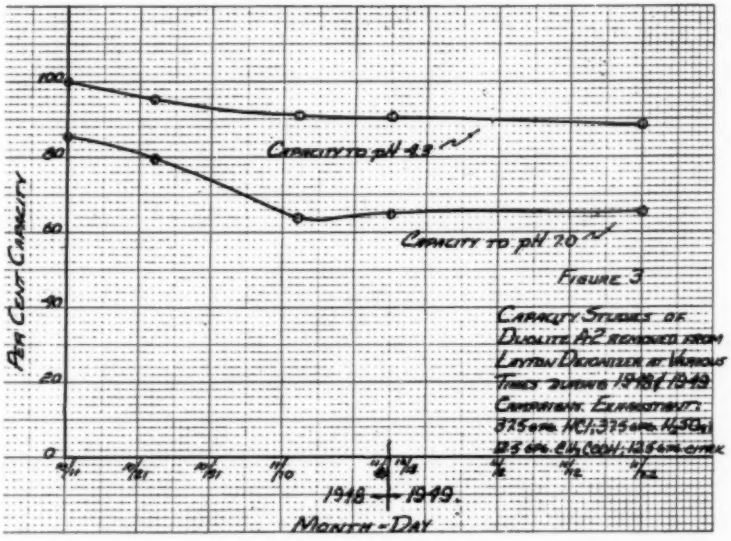


FIGURE 3

CAPACITY STUDIES OF DUOLITE A2 REMOVED FROM LAYTON DEIONIZER AT VARIOUS TIMES DURING 1948 & 1949. CAPACITIES EXPRESSED: 3.75 GMS. HCl; 3.75 GMS. H_2SO_4; 12.5 GMS. CH_3COOH; 12.5 GMS. OTHER

rest of the syrup and greens was set aside for brown sugar and edible syrup production. A continuous operation would naturally give us a better run than the short experimental run obtained in less than a day on 100 tons of molasses.

As more experience is gained on the deionization of beet sugar juices and sryups, it becomes more apparent that it is a useful tool, and well worthy of incorporation as a station in a beet house. Its many advantages, low molasses production, no rumbling or cleaning of heating surfaces, high purity juices, absorption of beet end fluctuations, etc., are dividends which cannot be ignored.

Simplified Sugar End Operation on De-Ionized Juices

HAROLD E. ELLISON[1]

There are many questions of concern which are suggested to all sugar men when they are faced with the proposition of handling unbuffered juices from ion-exchange, or of a purity of 97.5 to 98.5, as against handling a highly buffered beet juice of 91.5 to 92 purity. Sugar men with their ideas of what can and what cannot be done with sucrose solutions are very much in the same boat as the housewife who thinks she cannot use beet sugar for her finer cooking and preserving but must use cane sugar.

We have gone through all the stages of development with this new process which it is possible to go through in three years' time. First we started on a four-boiling system; from there we tried a seven-boiling system with all the necessary tanks to hold the various syrups to go through seven boilings and obtain a discard. This system was fairly satisfactory as far as purity, drops, etc., were concerned—but we found that we had a terrific buildup of color, and in order to maintain purities for three white strikes of sugar before the first melt strike, it was necessary to spike second and third strikes to the point that the ratio of No. 1, No. 2, and No. 3 was considerably off balance. Both the No. 2 and No. 3 strikes had a slight off-tint. We soon realized that in order to get top quality sugar there was much left to be desired in a six- or seven-boiling system. It appeared that in boiling three white strikes of sugar to the bag the quality of the second strike was slightly off, and the quality of the third strike was not high enough to bag alone; so that in blending the scond and third strikes with the first it made practically all the sugar lower quality than we should be satisfied with by using ion-exchange.

During our 1948 campaign we did considerable experimenting with a new decolorizer resin—Duolite S-30. We first started working in strict accordance with the instructions of the manufacturer. These instructions stated that S-30 was an acid reactor, and in order to obtain the best results from this decolorizer material, it would be necessary to use it between cation and anion. We soon found that this procedure entirely defeated the whole ion exchange process. We also found that the reaction obtained from S-30 was slightly caustic, but on sugar solution slightly alkaline. It had a very good capacity for color absorption; also it tended to strengthen some of the weaker acids which would ordinarily slip the regular cation-anion treatment. We also found that where you come out of ion exchange with a water-white solution, in evaporation there takes place a very definite browning action. We found in our experiments that there were one or two things we could do to stabilize color after ion exchange without any buffers.

As a result of our experiments in 1948, we set up in 1949 so that we could use a two-boiling system, which after the first three or four days was used almost to the full extent of our resin capacity.

[1] Superintendent Layton Sugar Company, Layton, Utah.

The procedure in our two boiling system was to boil No. 1 pan with comparatively light brix (vis. about 89.5), not especially light for ion exchange sugar. We used a superheated wash water, nine quarts to each machine load. All the wash and all the green were used to make No. 2 white. We started by adding 100 to 200 cubic feet standard syrup. Finally the second white strike was made only of wash and green from first. On No. 2 white we separated wash and returned right back to No. 2 pan, and the green went through decolorizer (S-30 resins) and back to measuring tank bumper, through carbs, kellys, and cation anion.

There are several advantages to simplifying juice handling and boiling system:

A. Through proper handling of juices after ion exchange and careful control of temperatures after evaporators to a high of 70° C. at the melters and a high in crystallization of 75° C. it is possible to hold good color for two white pans. We made sugar from second white as good in appearance as the sugar from first, but where we used nine quarts wash on first, we used fifteen quarts on second. On the separation of wash and green we attempted to hold wash above the purity of the second pan. It is hard to hold colors beyond the second pan good enough for a third white, so after the second boil we returned the green to S-30 resins and back to the beet end.

B. In bringing the second green back to the beet end we obtained a very good elimination of invert sugar through liming and carbonating. We finished the campaign with an average invert of thick juice of .12% on dry substance. The volume of material recycled did not build up invert at all. There were days when we recycled 100% of second green, and most of the campaign we were recycling between 50% and 75%. Our average was about 66%.

C. It is easy to see that in using a two-boiling system it is possible to get away from any unusual capacity in holding tanks. About the only tanks necessary are the hy-green syrup tanks under the first white centrifugals, two pan storage tanks for standard liquor, one pan storage tank for hy-green, one second wash tank under the second white centrifugals, one second green tank under second white centrifugals, and a gravity tank on pan storage for second green feed to decolorizers. These are plus any necessary tanks to hold blended syrups for production of soft sugars.

D. The two-boiling system makes it possible to schedule evenly the pan boilings so that the sugar boiler can give maximum attention to each pan boiled with other attendant benefits, vis., (1) Materially reduced stocks as the product of each pan is materially dependent on the progress of the other pan. Very seldom did we have two pans boiling at one time, and at one time when we took stock in the middle of of the campaign there were fewer than 2,900 bags of sugar in process compared to almost 8,000 bags at one time the year before. (2) It is possible to reduce total steam consumption in that the load is more constant and the boilers are not pushed at any time, attested by our

figure *Coal on beets* of 9.65%, the lowest figure for several years. (3) The discard is reduced in direct proportion to the volume of green you can recycle. It is possible to have anywhere from no discard to two or three discards, according to length of campaign and build up of raffinose sugar. (4) Greater boiler house efficiency is assured because of less fluctuation in load; the boilers can operate on the average load about 95% of the time, thus getting away from extreme peaks in load and complete dropping of load.

Ion exchange now—if we can obtain stability on resins, which looks very good by our experience—appears to be the most flexible development in the sugar field. It appears that the manufacture of sugar can now be simplified and improved so that we will be able to make sugar with a higher degree of certainty on both quality and quantity. It also opens up the possibility of making beet sugar a product of higher quality than is now credited to cane.

It now appears that with the very limited discard (two during a campaign) the extraction of sugar from beets can be held within the limits of the beet end losses plus unknown, which includes sweetening on and off and loss through inversion—all of which should be controlled to a point where it would be possible to get 97.5% to 98% total extraction. Layton sugar extraction for 1949 in granulated, brown, and liquid sugar was 96.5%.

Brown sugar is one phase of the sugar industry which has been a field entirely reserved for the manufacturers of cane sugar. We have been able to produce only a little on a synthetic basis after making the granulated and carefully blending cane syrups to spray on the sugar crystals. It is readily seen that such a process is too expensive an addition to make to our already expensive specialty lines, which the market price set-up makes impossible to justify. Only through ion exchange is it possible to compete with cane brown sugar. It is possible to take brown off the process any place down the line to the discard stage. The only off-taste in ion exchange brown is the taste of a caramel build up. There is none of the salty, bitter taste which is so noticeable in brown cane sugar. It is entirely possible that beet soft sugar will be more in demand than cane brown sugar because of the high percentage of mineral removal and the absence of any foreign flavors other than caramel.

Liquid sugar is one of the attractive phases of ion exchange, especially where the plant is close to a large center of population where a good demand for liquid sugar is possible. In other territories it is possible to develop enough market to utilize completely any discard molasses which might be produced from an ion exchange operation and at the same time convert this discard into sweetening power of a quality and volume to justify the operation. We have used a pilot scale plant in the last two years (which have been extremely short campaigns) to decrease the co.t of maintenance and hold together a full crew of key men which we would have had to decrease by four or five men otherwise.

Since the molasses market now bears a proper relationship to the price of granulated sugar, we have an added benefit to be obtained from the operation of an ion exchange plant.

After the conclusion of the 1949 sugar campaign we obtained two tank cars of straight house molasses to run for white sugar, brown sugar, and liquid sugar. We made no attempt to go the limit on white sugar extraction, but on a single pass we received 575 bags of white sugar; and with the experience gained it would be possible to make this sugar "A" grade. We also received 225 bags of brown sugar, and according to our calculations we should receive about 65 barrels of edible syrup at 70° brix.

When and if molasses becomes available to the extent that two or three months operation on molasses is practical, by the use of lime and recycling, we think it would be possible to extract easily 90% of the total sugar in the molasses as white sugar and possibly as much as 95% as white, brown, and edible syrup. We realize, of course, that the problems of molasses operation are different from beet operation; but the experience obtained shows us that it is certainly economically feasible.

Every year ion exchange is coming nearer to being the tool for sugar manufacturing which we had originally hoped it would be. In the past year we were able to get a broader insight into the eventual possibilities of the process and think we can see that it is sufficiently flexible so that the whole sugar process could be greatly simplified. Certainly it puts us in a more favorable position as compared to the cumbersome double process of raw and refined in the cane sugar industry.

We can by the use of ion exchange duplicate any standard of quality which can be set for the various sugars, and it is just possible that we can set up standards that heretofore have been unattainable.

Ion Exchange Operations—Hardin 1949 Campaign

J. E. MAUDRU[1]

Ion exchange operations at the Hardin plant during the 1949 campaign were quite satisfactory. The ion exchange operated almost continuously during the 86-day campaign with practically no mechanical difficulties. The flow of the juice to ion exchange was restricted to 80-85% of the total so that the beneficial buffering effect of the untreated 15-20% could be realized. pH loss through the evaporators at Hardin has been a problem and the use of excessive soda ash has been necessary. The 15-20% juice

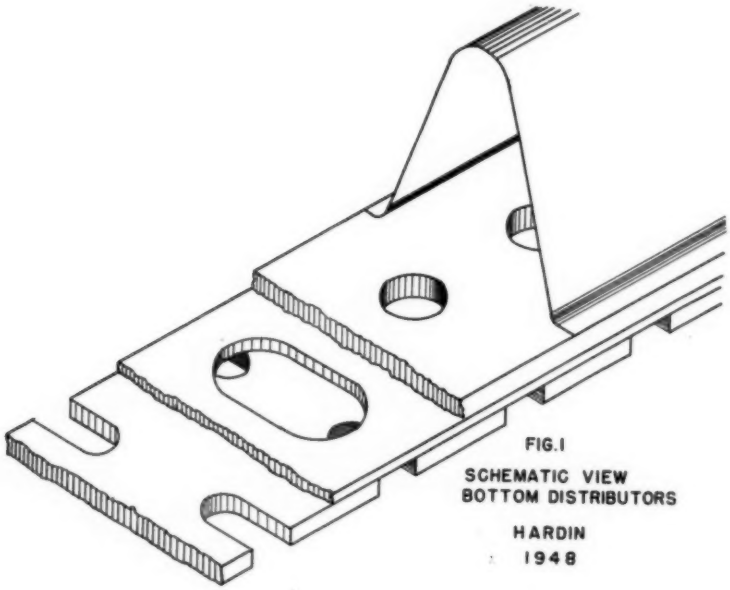


FIG.1
SCHEMATIC VIEW
BOTTOM DISTRIBUTORS
HARDIN
1948

bypass greatly diminishes this pH loss and soda addition. During the first part of the campaign 2nd carbonation juice constituted the influent to ion exchange, while during the last part of operations the juice was sulfured before being pumpd to ion exchange. The comparison of these two methods will be discussed later in the paper.

The only mechanical change in the ion exchange plant from the 1948 campaign was the bottom distributors. In 1948 a distributor diagrammed in Figure 1 was employed. This is composed of 3 strips of synthane, the

[1] General Chemist, Holly Sugar Corp., Colorado Springs, Colorado.

bottom strip being 3/16" thick, middle .018", and the top 1/8". The orifice is formed at the inside of the middle slot. The collector trough rests on top of the 3 synthane strips. It is made of rubber-covered stainless steel and conducts the juice from the orifices to a main juice trough along the diameter of the cell. There are 12 bottom distributors in each cell. The small tunnels ahead of the orifices plugged with resin so that excessive pressure drops through the distributors were encountered. Only about 50% of the juice was treated in 1948 due to this difficulty with distributors. During the 1949 intercampaign these distributors were replaced with a type having the orifice at the edge of the distributor, thus eliminating the tunnel. During this last campaign no trouble was encountered with excessive pressure drops or plugged beds. Figure 2 shows a typical head loss curve through both cation

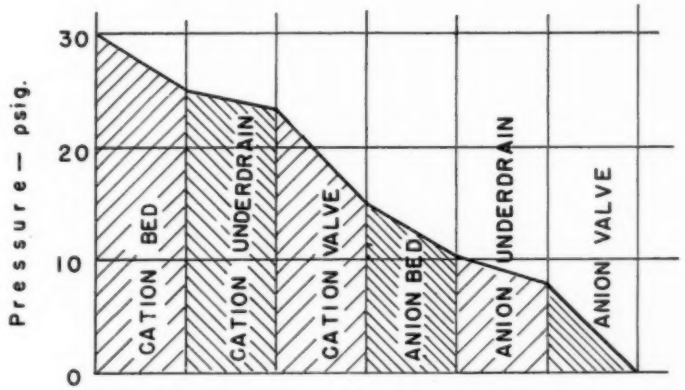


Figure 2

PRESSURE DROPS THRU ION EXCHANGE SYSTEM

Service Cycle

450 gpm.

and anion cells. The large head loss through the conoflow valves indicates of course, that the valves are throttled to maintain level. All figures are compensated for static head.

For the first time, last campaign, bacteria troubles were encountered. The infection took place in the heat exchangers and was actually more troublesome mechanically than from a sugar loss standpoint. The dextran material produced by the bacteria plugged the small passages of the heat exchangers so that frequent steaming out was required. No bacterial action was noted in the resin beds although they were sterilized several times using dilute formaldehyde after the method of Cruikshank & Braithwaite[2]. After starting to sulfur the feed to ion exchange this bacterial trouble diminished greatly, showing that the SO_2 in the juice exhibits some bactericide action.

[2] Cruikshank, G. A., & Braithwaite, D. G., Ind. Eng. Chem. 41, 472-3, (1949)

While 2nd carbonation juice is undoubtedly sterile due to the time-temperature and pH to which it has been subjected, the infection probably developed in the heat exchangers and never was completely eliminated in the steaming operations. The use of SO_2 paid for itself many times over in greatly reducing this problem.

We have always been concerned at Hardin about gypsum fouling of the cation resin due to the high calcium content of the Hardin water supply (6 gpg of Ca) as Ca (55 gpg total solids). During operations a cation bed was regenerated in the Na cycle with salt and then with acid. No increase

Table 1.—Ion Exchange Operating Data—1949. 1949 Campaign.

	Influent to Ion Exchange	Effluent from Ion Exchange
Brix	11.1	8.0
% Sugar	10.04	7.76
Apparent Purity	90.4	97.5
pH	8.8	8.4
Conductance uuhos	2849	628

Lb. Acid per Ton Beets	26.82
Lb. Acid per Cu. Ft. Resin	2.40
Lb. Ammonia per Ton Beets	8.05
Lb. Ammonia per Cu. Ft. Resin	.72
Non-Sugar Removal	75.66
% Dilution	23
Sugar in Molasses % on Beets	1.26
Cu. Ft. White Mass per Ton Beets	8.16
Cu. Ft. High Raw per Ton Beets	4.45
Cu. Ft. Low Raw per Ton Beets	1.23

in capacity after this treatment was noted and so it was concluded that no capacity was being sacrified on account of gypsum fouling.

Sugar end operations at Hardin were quite satisfactory and very little trouble with gummy low raws was experienced on the sugar end. Molasses production was not excessive and was about what pre-campaign calculations indicated. A typical white sugar analysis is as follows:

Ash %	.0038
SO_2 ppm	2
SO_3 ppm	2
Solution Grade	94

While the 1949 operations leave much to be desired, they are an improvement over previous years mostly due to the improved bottom distributors. An attempt was made to treat ion exchange just as any other station in the factory and to allow the local factory management to make the necessary decisions about operations and to integrate it into its proper place in relation to the other mill stations. In this we were highly successful, and plan to continue the program next year.

Second Carbonation Studies Based on Commercial Application of the "Effective Alkalinity" Concept

HUGH ROUNDS[1]

In October, 1947, H. Brunicke-Olsen of the Danish Sugar Company explained the "Effective Alkalinity" concept in the article, "The Physical Chemistry of Second Carbonation," published in the magazine "Sugar." Mr. Olsen and A. Brieghel-Muller elucidated further on the subject in the April, 1949, issue of "Sugar."

Effective alkalinity is measured on first carbonation juice and is that alkalinity which is active in binding carbon dioxide and deliming the juice. It is measured by taking the difference between alkalinity at titration to pH 9.25 (established as the most insoluble point for the calcium ion in a pure calcium carbonate water solution) and the lime content as measured by soap titration. Knowing this value, Mr. Olsen was able to predict the minimal lime content of the juice at saturation with carbon dioxide and the optimal alkalinity, that is, the alkalinity which should be maintained at second carbonation to produce the minimal lime content. The above relationships were expressed as curves which were found to lend themselves nicely to the control of second carbonation. These curves are shown in Figure 1. The principle of the *Effective Alkalinity Concept* may be compared to that of

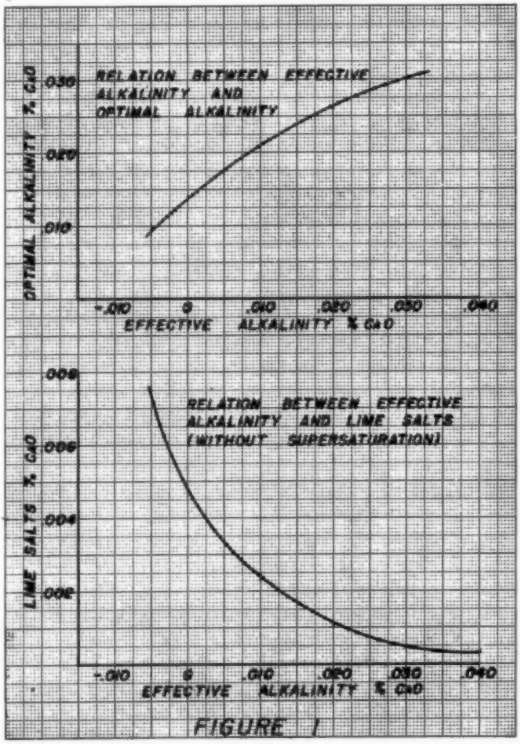


FIGURE 1

[1] The Amalgamated Sugar Co.

any solubility curve (that is, with a known constant temperature it is necessary to carbonate to an alkalinity at which the lime salts will be least soluble. This alkalinity, known as optimal alkalinity, is established only by first measuring the effective alkalinity). Table 1 describes the calculation of effective alkalinity.

Table 1. Calculation of Effective Alkalinity.

EXAMPLE	
Original pH 10.40 Titration to pH 9.25	
ML N/28 H_2SO_4	27.40
ML Soap Solution	17.40
Difference	+ 10.00
Effective Alkalinity= + .010% CaO	

The first efforts of the Amalgamated Sugar Company to apply this concept in the control of lime salts provided such promising results that a systematic examination of the commercial possibilities of this method of control was undertaken.

These studies extended through two campaigns. During the first campaign the work was limited to studies on a small experimental carbonator. The results in some cases showed that it was possible to obtain a very nearly complete elimination of lime salts. The principles of the pilot unit were then incorporated with a flocculator for the design of a new full scale carbonator which was installed at the Nampa, Idaho, mill.

During the following campaign examinations were conducted under normal operating conditions of the mill, and where special conditions were imposed they were established in the mill and not synthetically in the laboratory. The following is a discussion of the subjects examined and the results obtained:

(1) **Effective Alkalinity and Optimal Alkalinity.**

The new commercial carbonator with its three carbonating compartments offered an excellent opportunity to study the relationship between effective alkalinity and the optimal alkalinity in producing minimal lime salts. In the first carbonating compartment the juice was purposely undercarbonated, allowing an alkalinity slightly higher than the optimal point to exist. In the second compartment the juice was carbonated to the exact optimal alkalinity corresponding to the effective alkalinity. The juice was then further carbonated in the third compartment reducing the alkalinity to a point slightly below the optimal alkalinity. The lime salts were then determined on the effluent of each carbonating compartment and compared. In every case the lowest lime salts were obtained from the second compartment where the optimal alkalinity was held. Furthermore, these results showed that only a slight deviation from the optimal point resulted in a severe rise in lime salts.

(2) **Control of Second Carbonation and Soda Ash Addition by the "Effective Alkalinity" Method.**

To control second carbonation by this method it is only necessary to measure the effective alkalinity of the first carbonation juice and then carbonate to the corresponding optimal alkalinity as taken from the curve. In many cases, however, it was found that the effective alkalinities ran off the limits of the curve on the negative

side. When such is the case, it is possible to increase the effective alkalinity to any desired value by the addition of soda ash. It was decided to arbitrarily set the value of + .010% CaO as the effective alkalinity to which the lower values would be corrected.

It would then be possible to control second carbonation with optimal alkalinity corresponding to + .010% CaO effective alkalinity. Charts were established indicating for every value of effective alkalinity below this point the proper amount of soda ash to add to the process to produce the desired value. Thus there was established a logical, rational control of soda addition as well as second carbonation. The above principles were adhered to closely for the entire campaign in order that the results would be evaluated properly. Comparing these results with the previous campaign at the Nampa mill the following conclusions are drawn:

(a) Lime salts in filtered second carbonation juice were reduced 34%.

(b) Tons of beets processed for each evaporator body boil out were increased 46%.

(c) The amount of lime salts remaining in second carbonation was practically constant from hour to hour and day to day for the entire campaign. This was a contrast to previous campaigns when variations of lime salts as much as .100% CaO were not unusual from hour to hour.

(3) Effect of Temperature on Lime Salts in Second Carbonation Juice.

In the past there has been an open question as to the effect of higher temperatures in second carbonation on resulting lime salts. The argument for additional heat at second carbonation is based on the assumption that the residual lime salts exist wholly as bicarbonates which could be decomposed by the higher temperatures. Mr. Olsen's work shows also the presence of saccharate in residual lime salts and has indicated the possibility that saccharates may increase slightly faster at the higher temperatures than the bicarbonates decompose. Extensive tests ranging from 84° C., which was the average temperature at which juice is delivered to second carbonation without additional heat, to 94° C. showed no decrease whatsoever in lime salts at the higher temperatures. We have thus been able to effect greater heat economy by eliminating the second carbonation heater.

(4) Efficacy of the New Carbonator.

Realizing that a substantial decrease in residual lime salts had been effected, an attempt was made to determine whether or not any particular feature of the new design or the carbonator as a whole was responsible for this decline. Comparative examinations were made on lime salts existing in the individual compartments, under various gassing combinations, with the agitator in use and not in use and, finally, with the older conventional type carbonator in use. In all cases the residual lime salts varied but slightly or not at all. It was our conclusion that our new design was not superior to the conventional type in respect to the elimination of lime salts. It does, however, offer other advantages such as ease of control,

ability to retain sediment, provision of longer operating periods without the necessity of cleaning and ease of inspection. These features naturally make it the preferred carbonator at Nampa.

(5) Supersaturation of Residual Lime Salts.

These tests indicated, as did Mr. Olsens', that, even in adhering closely to the principles of effective alkalinity method of control, it was impossible to reach the minimal lime content calculated. The principal reason for this was proved to be the fact that the residual lime salts exist in a state of supersaturation. Only by completely breaking this supersaturation can the minimal lime content be obtained. This was accomplished easily in the laboratory by digestion of juice with crystalline calcium carbonate (about one percent) for a period of fifteen minutes at 85° C. The filtered juice lime content had been reduced almost to the minimal calculated value. In comparing the lime content in the last compartment of the carbonator with that in the filtered juice a substantial decrease was noted. It is believed that this is due to the partial breaking of the supersaturation as the juice encounters the calcium carbonate sludge in the filters. This phenomena was further exemplified when the entrance to a sample line in the carbonator became submerged in the lime sludge. The sample effluent became crystal clear, having been filtered through the precipitate, and its measured lime content approached the minimal calculated value. It had been hoped that incorporating the flocculating feature in the new carbonator would break the supersaturated condition of the residual lime salts by creating more effective contact with the precipitate. As previously mentioned, this agitation did not reduce the lime content. Additional milk of lime was added to the carbonator in hopes that a greater amount of precipitate would induce the desired result. Again the results were disappointing. So, while all evidence demonstrates the existence of this condition of supersaturation, no effective practical method has been found to break this supersaturation.

Summary

To summarize briefly, the results of the studies in second carbonation have led to the conclusion that the effective alkalinity concept provides a true and accurate control for second carbonation; that adhering closely to the principles of this concept was responsible for a 34 percent reduction in residual lime salts which allowed an increase of 46 percent in the tons of beets processed for each evaporator body boil-out at the Nampa mill; that this control can be applied to the conventional type carbonator with equal success; that temperatures higher than 84° C. do not create a reduction in lime salts at second carbonation, and, therefore, greater heat economy can be effected by the elimination of the second carbonation heater; that the residual lime content cannot be reduced to the calculated minimum until a method of eliminating the supersaturated condition of the lime salts after second carbonation can be devised.

The Amalgamated Sugar Company has now adopted the *Effective Alkalinity Concept* as the standard method of control of second carbonation. Reports continue to bear out the validity of these findings.

Composition of Beets Grown in Widely Separated Areas

H. W. DAHLBERG[1]

From time to time during the past twenty years our research laboratory has made rather complete analyses of 24-hour composite samples of cossettes. These samples are normally taken on the same day in October and cover six to ten factories, so located that we know they cover different climatic conditions and to some extent different soil types. By comparing these figures over a period of years we can recognize certain trends in quality of beets and try to correct them as far as possible by improved cultural methods and improved seed varieties.

This year I decided it would be interesting to secure samples from a much wider area, so will in this paper report results of 24-hour composite cossette samples from the following ten factories:

Brighton, Colorado
Eaton, Colorado
Brush, Colorado
Gering, Nebraska
Lovell, Wyoming
Nyssa, Oregon
Mason City, Iowa
Garden City, Kansas
Picture Butte, Alberta
Winnipeg, Manitoba

The last three factories were chosen in order to include northern and southern latitudes, Picture Butte and Winnipeg being at a latitude of approximately 50° and Garden City at 38°. The effect of latitude on the quality of beets is rather well known: a northern latitude normally produces a high quality beet. This year, however, the quality of beets at the two Canadian factories was below normal, particularly at Picture Butte, where I understand serious damage was done by root aphids. The Winnipeg area suffered a serious drouth during July, August and September which hurt the quality of beets grown there.

On the whole, the analyses in the following tables show more uniformity in the ash constituents than I expected. The quality of beets was generally good, being above 85.5 purity in all cases except Garden City. Climatic conditions at Garden City are those of a southern latitude, tending to produce beets of low purity and high ash content. It will always be true that a climate which produces excellent yields of corn will not produce high quality sugar beets.

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[1] Director of Research, Great Western Sugar Company.

Table 1.—Research Laboratory—The Great Western Sugar Company Analysis of Cossettes of 1949-50 Campaign.

Factory	Brighton	Eaton	Brush	Gering	Lovell	Nyssa	Mason City	Garden City	Canadian		
									Picture Butte	Manitoba High Sugar	Manitoba Low Sugar
FACTORY ANALYSIS											
% Sugar	17.36	16.62	15.32	15.24	16.68	15.64	16.92	14.08	15.28	18.6	16.6
Purity	88.6	88.8	87.7	87.3	89.4	90.2	86.7	80.6	87.1	[1]85.7	85.5
RESEARCH LABORATORY ANALYSIS											
Percent on Original Beets											
% Dry Sub.	22.50	22.69	20.32	21.28	22.27	19.77	22.67	20.12	20.59	24.40	20.46
% Total—N	0.147	0.147	0.146	0.172	0.137	0.145	0.230	0.184	0.155	0.202	0.235
% NO_3—N	0.0098	0.0056	0.0055	0.0318	0.0150	0.0049	0.0109	0.0118	0.0231	0.0060	0.0119
% Ash											
Total	0.615	0.650	0.747	0.716	0.754	0.589	0.691	0.887	0.828	0.815	0.842
Corrected for Insoluble	0.592	0.613	0.670	0.697	0.544	0.566	0.666	0.843	0.714	0.676	0.783
% CaO	0.0435	0.0428	0.0381	0.0421	0.0529	0.0410	0.0396	0.0374	0.0923	0.0703	0.0396
% MgO	0.0694	0.0705	0.0665	0.0662	0.0743	0.0626	0.0857	0.0721	0.0695	0.0783	0.0958
% K_2O	0.237	0.264	0.280	0.293	0.200	0.219	0.283	0.348	0.237	0.210	0.340
% Na_2O	0.0353	0.0415	0.0569	0.0518	0.0421	0.0412	0.0404	0.0871	0.0776	0.0911	0.0509
% P_2O_5	0.0683	0.0517	0.0527	0.0471	0.0593	0.0632	0.0561	0.0674	0.0517	0.0558	0.0578
% SO_3	0.0211	0.0235	0.0258	0.0196	0.0224	0.0207	0.0255	0.0300	0.0226	0.0248	0.0246
% Cl	0.0364	0.0380	0.0728	0.0458	0.0314	0.0334	0.0260	0.1058	0.0230	0.0276	0.0354

[1] Purity of Press Juice

The following comparisons may be of interest, particularly from the standpoint of molasses production:

Factories with Ash Content Below 2.80% on D.S.		Factories with Ash Content Above 2.80% D.S.	
Lovell	2.44%	Nyssa	2.86%
Brighton	2.63	Mason City	2.94
Eaton	2.70	Gering	3.28
Manitoba (High Sug.)	2.77	Brush	3.30
		Picture Butte	3.47
		Manitoba (Low Sug.)	3.83
		Garden City	4.19

There is considerable variation in the total nitrogen content, % on dry substance, and these figures also have an important bearing on molasses production.

Factories with Nitrogen Content Below 0.76% on D.S.		Factories with Nitrogen Content Above 0.75% on D.S.	
Lovell	.616%	Gering	.806%
Eaton	.649	Manitoba (High Sug.)	.827
Brighton	.656	Garden City	.913
Brush	.718	Mason City	1.015
Nyssa	.734	Manitoba (Low Sug.)	1.149
Picture Butte	.751		

The detailed figures for the analyses are given in Tables 1 and 2.

The following comments are made on some of the outstanding differences in the analysis of the ash itself.

Picture Butte has a curiously high CaO content and the low sugar sample from Manitoba is abnormally low in CaO.

Beets from the most northerly latitudes—Lovell, Nyssa, Picture Butte and Manitoba—have the lowest K_2O content in the ash. This is probably due more to climatic conditions than it is to the available potash in the soil.

The analyses of beets from this wide area confirm the conclusions we had reached previously from hundreds of analyses made of beets in Great Western territory. These conclusions are that mature beets of high sugar content and purity normally have the following characteristics:

Low ash
Low total nitrogen
Low nitrates
Low sodium content
CaO plus MgO = 18% or more of the soluble ash

Beets with the above characteristics should give a non-Steffen sugar loss in molasses of 1.7 to 2.0% on beets. Mr. Fort reported in his June, 1949,

Table 2.—Analysis of Cossettes of 1949-50 Campaign—(Continued)

Factory	Brighton	Eaton	Brush	Gering	Lovell	Nyssa	Mason City	Garden City	Canadian		
									Picture Butte	Manitoba High Sugar	Manitoba Low Sugar
					ANALYSIS—% on Dry Substance						
Total—N	0.656	0.649	0.718	0.806	0.616	0.734	1.015	0.913	0.751	0.827	1.149
NO_3—N	0.004	0.025	0.027	0.149	0.067	0.025	0.048	0.059	0.112	0.025	0.058
Ash—Cor.	2.63	2.70	3.30	3.28	2.44	2.86	2.94	4.19	3.47	2.77	3.83
% CaO	0.193	0.189	0.188	0.198	0.237	0.207	0.175	0.186	[1]0.447	0.288	0.194
% MgO	0.308	0.311	0.328	0.311	0.334	0.317	0.378	0.358	0.338	0.321	0.468
% K_2O	1.05	1.16	1.37	1.38	0.90	1.11	1.25	1.73	1.15	0.86	1.66
% Na_2O	0.157	0.183	0.280	0.243	0.189	0.208	0.178	0.433	0.377	0.373	0.249
% P_2O_5	0.304	0.228	0.260	0.221	0.266	0.320	0.248	0.335	0.251	0.229	0.282
% SO_3	0.094	0.103	0.127	0.092	0.100	0.105	0.113	0.149	0.110	0.102	0.120
% Cl	0.162	0.167	0.359	0.215	0.141	0.169	0.115	0.526	0.112	0.113	0.173
					ANALYSIS OF ASH—% on Ash						
% CaO	7.34	6.99	5.68	6.04	9.71	7.25	5.95	4.44	[1]12.93	10.40	5.06
% MgO	11.72	11.51	9.92	9.50	13.65	11.06	12.87	8.56	9.74	11.58	12.23
% K_2O	40.0	43.1	41.7	42.0	36.8	38.7	42.5	41.3	33.2	31.1	43.4
% Na_2O	6.0	6.8	8.5	7.4	7.7	7.3	6.1	10.3	10.9	13.5	6.5
% P_2O_5	11.54	8.44	7.86	6.75	10.89	11.17	8.43	8.00	7.25	8.25	7.37
% SO_3	3.57	3.83	3.85	2.82	4.11	3.66	3.83	3.57	3.17	3.67	3.14
% Cl	6.15	6.20	10.87	6.57	5.77	5.90	3.90	12.55	3.22	4.08	4.52

[1] Checked

"Report of Studies on the Uniformity of Quality of Beet Sugar," that the average sugar loss in molasses for 35 non-Steffen factories in the U.S.A. for the last ten-year period was 2.13% on beets.

It would be of interest if a number of sugar companies would make similar analyses of cossettes and report them at the next meeting of the Society. It would be of especial value to have more analyses from the non-irrigated areas east of the Mississippi, from beets grown in the peat soils of California and from beets grown through the winter in the Imperial valley.

I am indebted to our research staff for the detailed analyses reported in this paper, and to the various sugar companies which kindly furnished the samples of cossettes.

Size Distribution of Sugar Crystals

ANDREW VANHOOK[1]

Introduction

The size distribution of finished crystals is valuable for practical purposes, as well as for theoretical revelations concerning the mechanism of crystal growth. The former aspect, in the specific case of sucrose, is dealt with in Spencer-Meade's *Handbook* (18),[2] and Browne and Zerban (3); by Mr. Nees at the Denver meeting of this Society (11), Mr. Fort in his *Reports of Studies on the Uniformity of Beet Sugars* (4), Mr. Powers of Tate and Lyle, Ltd. (13), and by many others (12, 16, 19). The demands of the trade; and the influence of crystal size on behavior in the centrifuge, on packaging, handling, and caking, are considered in these several references.

The connection between size distribution and mechanism of growth has not yet been analyzed in the case of sucrose, to the writer's knowledge; and it is the purpose of this paper to consider this matter.

Results

Powers (13) has summarized the screen analyses of a variety of refinery products, and finds the arithmetic-probability plot to be linear between 10 and 90% (13a), or even better (13b), for most commercial products. The writer has plotted the screen data of several hundred examples from various sources (2, 4, 8, 13b, 19, 21a), in many different ways (1, 5); and finds this same arithmetic-probability plot to be the most satisfactory manner of representation. It is linear, in most cases, between the 2 and approximately 90% values. Beyond these limits the deviations are generally of the nature indicated in Figure 3, and they are seldom symmetrical on the high and low ends. These data are mostly for commercial products; which, Fort (4b) has pointed out, "are a mixture of strikes made from massecuites of widely variable purity — and may not yield consistent probability curves." The test in the case of individual strikes (13b, 19, 21a) is not only superior, but very significant in indicating the mechanism of the crystal generating and growth processes.

Discussion

Since the growth of sucrose crystals is proportional to the growing area (7, 10), the Gaussian distribution, which is observed, immediately suggests a purely chance distribution (6, 15) of the originating centers of growth. This, of course, is exactly the situation in the case of any seeding procedure, and even in the case of boiling to grain as for many of Thieme's data (19). It implies the induction of graining by inoculation, or via a heterogeneous process, and this is probably the case in usual sugar house work (21b).

The observed distribution remains nearly normal when extraneous nucleation is avoided by careful vacuum evaporation without ebullition, as described by Schweizer (17). This similar distribution seems reasonable

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[2] Numbers in parentheses refer to literature cited.

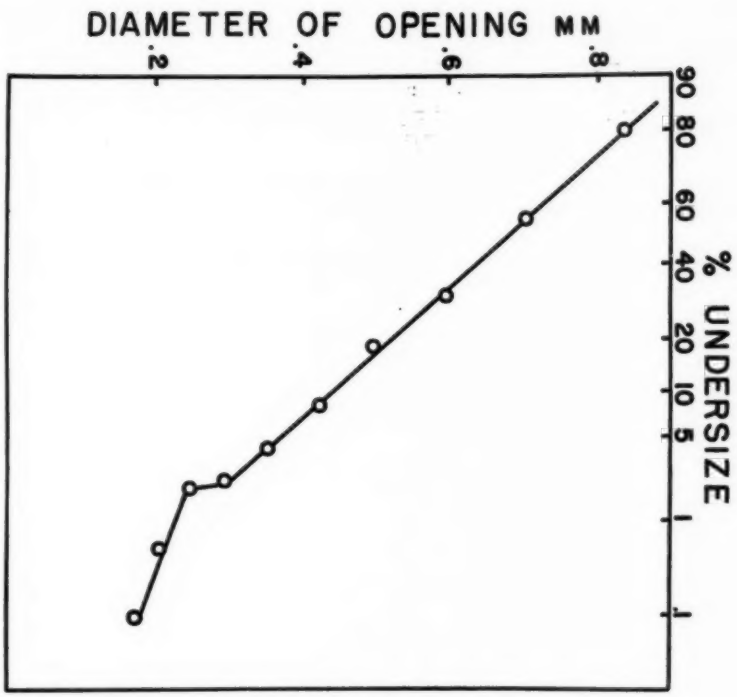

Figure 1. Abnormal Type of Distribution Curve.

when it is recognized that the onset of nuclei formation is very sensitive to concentration changes—in fact, virtually critically so (21b). This sudden establishment of a high concentration of nuclei of various sizes will depend upon the frequency of collision between particles, and it seems not unreasonable that this occurs according to kinetic theory, and, hence, is described by the normal distribution law (9, 15). This same behavior has been observed at concentrations below that required for normal, homogeneous nucleation, when prolific graining was induced suddenly by ultrasonic irradiation (20). The size distribution was again normal, and, as in the above case, the uniformity was vastly better than that observed in commercial products: viz.

Coefficient of Variation (13), or σ	
Specified for standard granulated (13b)	20-25%
Homogeneously nucleated at an Oversaturation of 1.6	14.8, 19.3%
Ultrasonic irradiation at 0 = 1.1 (Average of 4 trials)	11.7%

The above deductions and observations are completely in accord with the mathematical analysis of Roginski and Todes (14). These workers find that the normal type of size distribution results if crystallization proceeds from seeding without independent formation of nuclei, or when the rate of nucleous formation falls off rapidly with a decrease in supersaturation. This is not observed to be always the case with most substances (1), even though it represents the basic mechanism involved in nucleus formation and subsequent growth (22).

Several instances were encountered in the present survey in which distinct breaks in the normal probability curve were observed. Fig. 1 represents such a case. This abnormality is probably the result of the product being a blended mixture of otherwise normal components, or an interruption in the normal growth of a single strike. Loveland and Trivelli (9) have shown how these and related cases may be normalized by means of the *lognormal* distribution (6):

$$n = \frac{\Sigma n}{\ln \sigma \sqrt{2\pi}} e^{-(\ln x - \ln M)^2 / 2 \ln^2 \sigma}$$

where n is the number of particles of size x, M the mean size, and σ the standard deviation. The conversion to weight fractions is readily carried out (1, 5, 11); although this is not necessary, since the function is independent of the size parameter. Physically, this modified frequency law is a skewed form of the normal Gauss law, and it emphasizes the seemingly independent portions of any composite curve as well as the dissymmetry at both ends.

In view of the success of the normal distribution function in describing most of the data on sucrose crystals, and in the lack of positive information about the unusual cases, a detailed analysis by Loveland and Trivelli's methods has not been attempted. The deviations from the normal curve on the fine and coarse ends are probably due to the removal of these extreme sizes by screening, as well as the occurrence of dust on the surface of larger particles. Fig. 2 illustrates this latter effect. Obviously these extreme fines will not be counted as such by the usual procedures; thus contributing to the low undersize values which are usually observed. If the size count is made on unscreened and undried product, the linearity on the small end is greatly extended. Likewise, the deviations on the coarse end are, presumably, due to agglomerates, and these are frequently apparent upon microscopic examination. If agglomerates are reduced by careful dispersion before measurement the linearity on the coarse end is improved, but the contrary effect increases on the other extreme. This is probably the result of attrition, for the same effect is noted when false grain is formed in ordinary boiling (19).

Figure 2. (See page 573). Electron Micrographs of Sugar Crystals (Confectioner's Grade A)

A. Original crystal, SiO_2 replica, 4200X.

B. Water Etched, SiO_2 replica, 4200X.

C. Water Etched, Formvar replica, Uranium shadowed, 7600X.

(Courtesy Stamford Research Laboratories, American Cyanamid Co.)

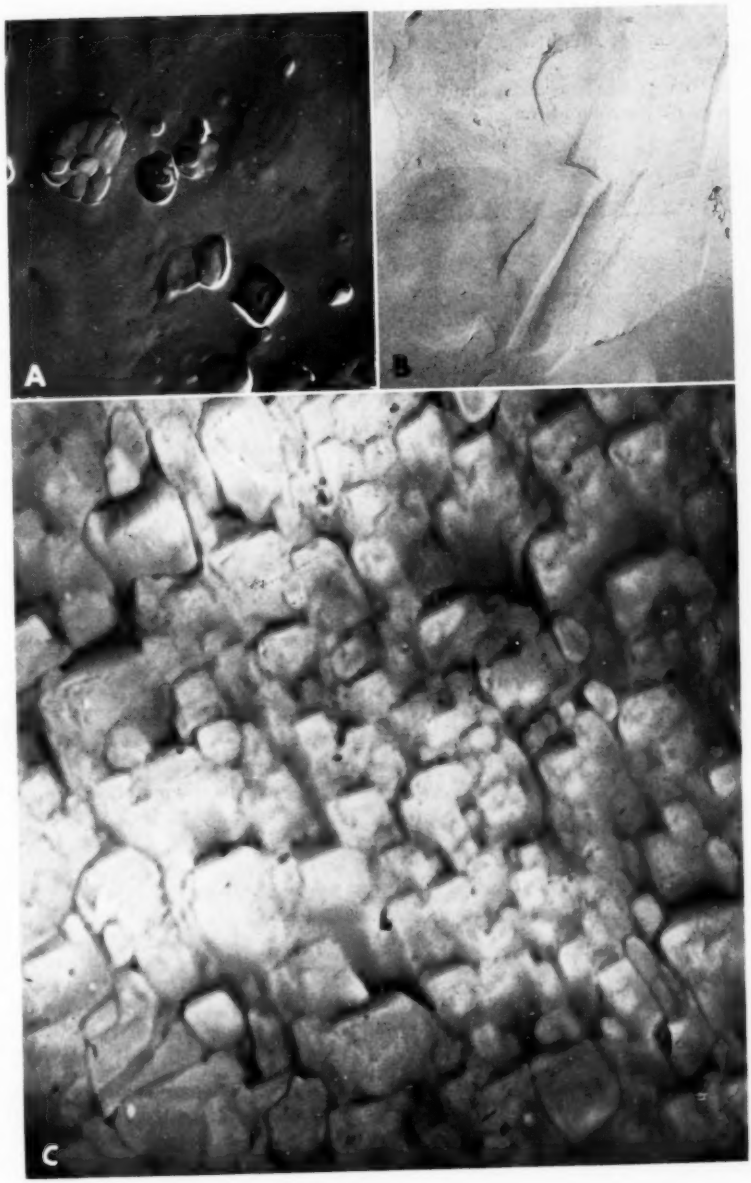

Figure 2.

Both effects may be minimized by boiling a low purity strike (experimental); in which case agglomeration is greatly reduced. The linearity was observed to be vastly improved in this case, as evidenced in Fig. 3. In this plot a specific example of a similar size commercial product (13) is given for comparison.

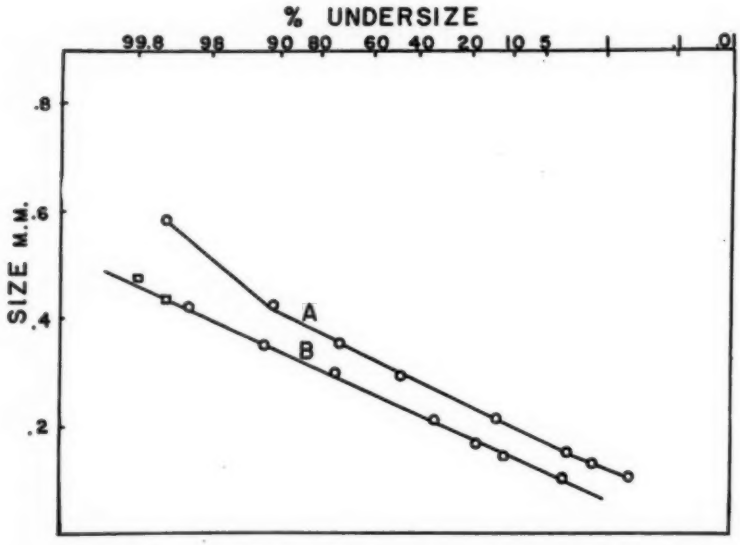

Figure 3. Frequency curves of high purity (A) and low purity (B) strikes.
A—Caster grade, refined (13b)
B—Experimental strike, boiled to grain at 80° purity; Cuban stock, counted wet.
o—Screen sizes
□—Microscopic sizes

Summary

The size distribution of most sugar crystals follows the arithmetic-probability curve very well within wide limits. This suggests a heterogeneous mechanism of nucleation in the usual boiling procedure, and a critical dependence of nucleation on supersaturation when all foreign nuclei are excluded.

Occasional discontinuities may be accounted for by interruptions in the boiling or by the blending of finished products. Deviations at extreme sizes are accounted for by the previous removal of these sizes in commercial work and the presence of agglomerates and uncounted fines when these fractions are present.

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Aconitic Acid in Sugar Beets

LLOYD W. NORMAN, JAMES H. TURNER AND
ROBERT H. COTTON[1]

In light of recent interest in the use of aconitic acid and its derivatives in the plastics industry (1)[2] and because of new developments in methods of recovery of this substance from plant juices, especially sugar bearing plants, (2, 3) an investigation was undertaken to determine the quantity of aconitic acid in sugar beets.

The finely ground beet samples were digested two hours in a 1-2% sulfuric acid solution filtered and analyzed for total aconitic acid (free and combined) by the Saffran-Denstedt modification of the Furth-Herrmann colorimetric method (4). Data obtained are shown in the following table:

Sample	Origin of Sample	Percent Aconitic Acid (Original Weight Basis)	Number of Samples
Beet roots	Sacramento Valley, Calif.	0.083	4
Crowns	Sacramento Valley, Calif.	0.084	4
Leaf Blades	Sacramento Valley, Calif.	0.031	4
Leaf Petioles	Sacramento Valley, Calif.	0.011	4
Leaf Blades	Arkansas Valley, Colo.	0.028	2
Leaf Petioles	Arkansas Valley, Colo.	0.009	2
Beet roots	Imperial Valley, Calif.	0.021	9
Whole Leaves	Imperial Valley, Calif.	0.035	8
Pulp Press Water	Imperial Valley, Calif.	0.002	15

As a check of the Furth-Herrmann method two large samples of pulp press water (the water pressed from the exhausted cossettes) were evaporated down and analyzed by the Roberts-Ambler decarboxylation method (5). The results were 0.007% and 0.002% for the Furth-Herrmann method compared with 0.0076% and 0.0057% for the Roberts-Ambler method. In light of the very small amounts involved these checks were considered satisfactory.

We believe that in view of the very low amount of aconitic acid found in this investigation commercial utilization of sugar beets or their by-products as a raw material for the recovery of this product is not feasible.

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[2] Numbers in parentheses refer to literature cited.

Organic Acids in Sugar Beet Diffusion Juices[1]

J. B. STARK, A. E. GOODBAN, AND H. S. OWENS[2]

Research and Marketing Act funds have been allotted to the Western Regional Research Laboratory for work on the technology of sugar beets. Liaison between the Laboratory and industry has been established through the Committee on processing problems, appointed by the industry. This committe has met at the Laboratory to discuss subjects meriting investigation and has proposed four problems: (1) *study of the composition of sugar beets;* (2) *study of the chemistry of betaine and the synthesis of derivatives which might have industrial possibilities;* (3) *determination of the changes in composition of processing liquors;* and (4) *investigation of the causes and amelioration of scaling.*

This paper will report results thus far obtained during the current campaign on the composition of diffusion liquors. It can be considered only preliminary. The object of this work is two-fold: to discover substances which might have by-product value and to improve technology of sugar-beet processing through application of knowledge of composition.

Materials and Methods

Diffusion juices investigated were obtained early in the campaign from Manteca, California; Centerfield, Utah; Rupert, Idaho, and Sidney, Montana. Preliminary work was done on diffusion juice prepared at the Laboratory from about two tons of beets procured from Alvarado, California. Precautions, such as concentrating and/or adding toluene, were taken to preserve the samples. On receipt they were placed in storage at 3° C.

Amino acids have been identified chromatographically by the method of Consden, Gordon, and Martin (1)[3], in which phenol-water is the developing solvent and ninhydrin the indicator. Estimation of the concentration of each of the amino acids has been undertaken by use of selected strains of micro-organisms. Quantitative determinations of chloride, sulfate, citrate, and phosphate by published methods are under way. Ion exchange resins used in this study were A293M and A300, American Cyanamid Co.; A4, A5 and A6, Chemical Process Co.; D735 and S, Permutit Corp.; IR4B and IRA400, Resinous Products Corp.; and Dowex 50, Dow Chemical Co.

It became apparent that complete analysis of many samples of diffusion juice would be impossible if conventional methods were applied; however, separation of acids on ion exchange resins, followed by fractional elution and titration of the fractions, offered a possibility of yielding the desired results. A number of resins were examined with respect to capacity and length of time required to establish equilibrium. One-gram samples of resin were equilibrated overnight with 25 ml. of 1*N* solutions of oxalic,

[1] Report of a study made under the Research and Marketing Act of 1946.
[2] Western Regional Research Laboratory, Albany, California; Bureau of Agriculture and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.
[3] Numbers in parentheses refer to literature cited.

citric, or succinic acid. The supernatant liquid was titrated with standard alkali. Table 1 shows that, of the resins tested, D735 and S had high exchange capacity for both oxalic and succinic acids; the former is the strongest and the latter the weakest organic acid found in sugar beets. When resin S was in the base form, carbon dioxide formation was encountered which caused disruption of boundaries and mixing of the components of the column. Resin S was used without such difficulty in the salt form.

Table 1.—Capacity of some anion exchange resins for oxalic, citric and succinic acids.

Resin	Amount of acid absorbed (m.e./g.)		
	Oxalic	Citric	Succinic
A293M	11.0	9.5	7.5
A300	14.7	15.2	10.4
A4	11.2	8.6	6.9
A5	12.4	5.9	7.4
A6	11.3	4.0	6.1
D735	15.2	15.3	11.3
S	16.0	15.9	11.2
IRA400	5.4	5.3	5.1

Equilibrium was 98 to 99% complete within 7.5 min. when 0.2*N* oxalic acid was added to any of the resins. Other tests with S and D-735 showed that adsorption of 0.1*N* hydrochloric acid is sufficiently slow so that flow rates should be about 0.1 ml./cm.^{2}/min. with resin ground to pass a 40-mesh and to be retained on a 60-mesh screen.

The columns of resin used for this work have been 1.6 to 1.8 cm. in diameter and 30-50 cm. in length. The resins were ground to either 60-80 or 80-100 mesh. With the resin in the base form, sufficient acid from the diffusion juice was added to change the color of the resin for the first two cm. of depth. Initial flow rates for adsorption of the acids and subsequent elution with sulfuric acid at pH 1.5 were between 0.1 and 1 ml./cm.^{2}/min. This concentration of eluting acid was chosen to provide as great as possible spread between percentages of unionized acids likely to be present as determined from calculated curves of pH vs. percent ionization. The size of the fraction was between 3 and 6 ml., depending upon the flow rate.

In an attempt to achieve better separations of the acids, use was made of resin S in the chloride form washed to pH 3 with distilled water. Dilute sulfuric acid (pH 1.2 or 1.7) was the eluting medium. Flow rates were 0.1 — 0.2 ml/cm.^{2}/min. and resin size was 80-100 mesh.

Results

The composition of European-grown sugar beets has been studied extensively but quantitative information is relatively incomplete. Considerable doubt still exists whether some of the compounds reported present in beets are the result of microbial action or of processing conditions (2). Published knowledge of the composition of sugar beets grown in the United States is less complete. To obtain information on the magnitude of the problem, the number and nature of compounds present in a diffusion juice prepared from Alvarado, California, beets was investigated. Exploratory work was done with papergrams which indicated the presence of several amino acids.

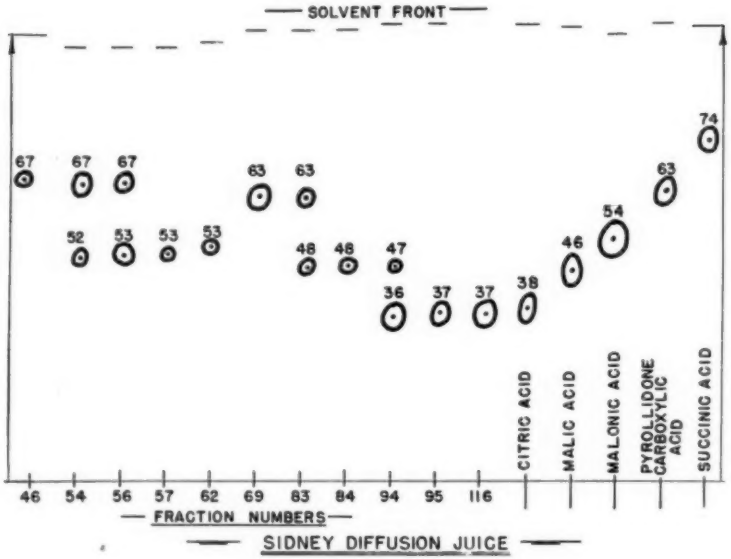

Figure 1. Papergram of certain acid fractions from Sidney, Montana, diffusion juice. Developing solvent *t.* butyl alcohol 1 part, benzyl 3 parts, isopropyl alcohol 1 part, water 1 part, and 1% formic acid, indicator brom cresol green. Resin in chloride form, eluting rate 0.15 ml./cm.²/min. Numbers above the spots refer to the distance moved by the organic acid relative to the movement of the solvent.

These were identified by their growth-promoting action on selected strains of bacteria and are glycine, α-alanine, leucine, isoleucine, valine, glutamic acid, aspartic acid, and threonine. Tyrosine and phenylalanine were present in trace quantities. The latest review available on composition (2) lists only lucine, isoleucine, aspartic acid and glutamic acid as present in beet juice.

Other organic acids have been separated by chemical means and have been identified as citric, oxalic, lactic, succinic, malic, and mucic acids. In addition the presence of glycolic, glutaric and pyrrolidone carboxylic acids is indicated from chromatograms.

Information will be published separately on a tenth acid, which has proved to be a dimer of pyrrolidone carboxylic acid through a methylene bridge on the amide groups. This acid is probably an artifact developed because of use of formaldehyde as an antiseptic during diffusion, followed by concentrating the juice to 80% refractometric dry solids. It is the only acid with the exception of mucic acid, so far isolated in the course of this work which has not been mentioned in the literature on sugar beets.

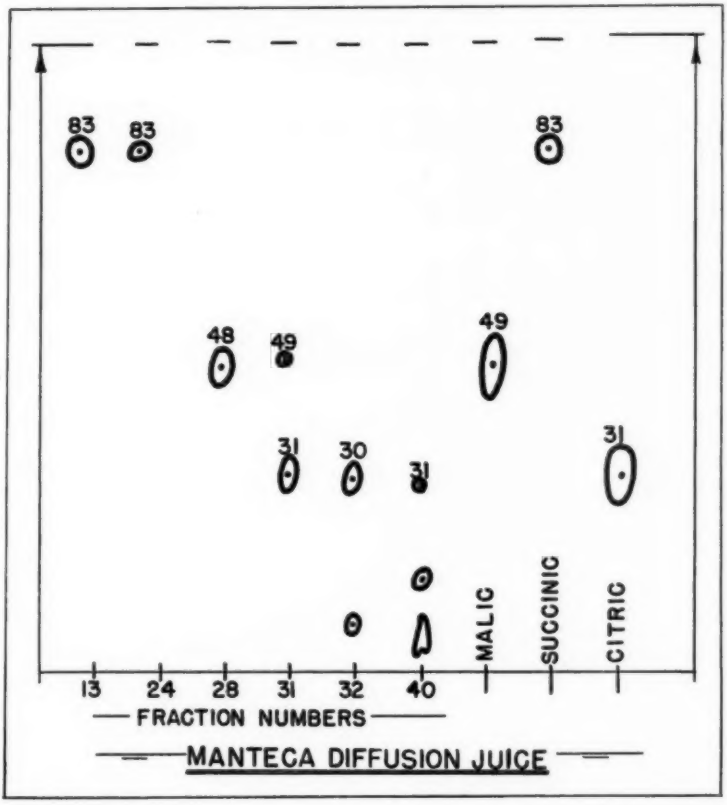

Figure 2. Papergram of certain acid fractions from Manteca, Calif., diffusion juice. Developer: chloroform 1 part, 95% ethanol 1 part, formic acid 1%. Resin in base form, flow rate 1 ml./cm.²/min.

The effectiveness of fractionations with ion exchange resins is best illustrated in Figures 1 and 2. Lactic acid, moving to spots labeled 67 and 83 in Figures 1 and 2 respectively, is separated from citric acid. Although not shown in the figures, citric acid is separated from oxalic acid. Overlapping occurs when malic or pyrrolidone carboxylic acid is present. Separation of these acids is somewhat improved by means of resin in the chloride form. The diffusion juices contain malic, citric and oxalic acids; also, except for the juice from Manteca, there is some pyrrolidone carboxylic acid. The latter might be an artifact because of its lack of appearance in the unconcentrated diffusion juice from Manteca. Glycolic acid is apparently present in the Sidney juice. Lactic acid is present in all the diffusion juices

examined. These results indicate that of the 15 non-amino acids reported present in beets (2) most are present in concentrations less than 0.05%.

Tables 2 and 3 summarize quantitative data on all the acids.

Table 2.—Concentration of some amino acids in sugar beet diffusion liquors.

	Manteca	Rupert	Sidney	Centerfield
	mgm/l at 10% refractometeric dry solids			
α—Alanine	(56)[1]	present	present	20[2]
Aspartic Acid	150	79	109	63
Glutamic Acid	182	82	62	(224)
Isoleucine	73	24	28	present
Leucine	71	20	28	(13)
Threonine	52	14	19	(18)
Valine	59	13	32	(11)
Van Slyke N	310	84	67	105

[1] Figures in parentheses are single microbiological determinations. Others are an average of two determinations.
[2] Estimated from papergrams, using known amounts of alanine in the standard run on the same paper.

Values for lactic and malic acids were obtained from fractionations and might be too high because of the possible presence of other unidentified acids. For example, adipic and glutaric acids have been reported (2) and they would be probably in the same fractions as lactic acid.

Table 3.—Concentration of organic acids other than amino acids in sugar beet diffusion juice.

	Location of sugar beet factory			
Acid anion	Manteca Calif.	Rupert Idaho	Sidney Montana	Centerfield Utah
	(mg./l at 10% rfractometric dry solids)			
Chloride	<60	39	82	329
Sulfate	120	105	158	171
Phosphate	402	307	475	278
Oxalate	770	<31	32	92
Citrate	510	505	655	700
Lactate	1960[1]	present	70[1]	1730[1]
Glutarate	present	----	present	----
Malate	480[1]	194[1]	312[1]	present
Glycolate	present	----	49[1]	present
Pyrrolidone Carboxylate	----	880[1]	420[1]	present
Total acid (meq/l)	73.3	39.2	63.9	60.5
Known acid (meq/l)	71.9	31.4	41.3	54.3

[1] Values obtained from titration of fractions from anion exchange columns.

To establish a limit to this work, we applied VanHook's (3) equation relating rate of crystallization of sucrose to concentration of impurities. A relatively high value of 2 was assumed for the constant i and a 25% decrease in rate of crystallization of sucrose in molasses was set as the minimum effect to be considered. Resulting calculations gave a concentration limit for substances in the original diffusion liquor near 0.005%. Substances below that limit will not be investigated unless they possess promising biochemical properties or are present to a greater extent in one of the juices under examination.

Discussion

Examination of the results indicates that no compound found has extraordinary value as a by-product. The production of some organic acids in factories using ion exchange treatment might warrant further study.

Discussion of the application of these results to the technology of sugar beets will be reserved for a later paper. It is apparent that of the compounds investigated the presently applied method of defecation could remove only oxalate and some citrate, phosphate and sulfate. Practically all of the other compounds investigated in the course of this work would go through the processing procedure with little or no change. There might be other methods, in addition to ion exchange, which would remove more of the non-sucrose impurities from diffusion juice.

Considerable variation in the composition of sugar-beet juices from different growing areas is apparent. Variations in inorganic constituents probably reflect differences in soil composition, fertilizer practices, hardness of water used in diffusers, variety, and possibly climate. These variations might influence the organic constituents, because biochemists in recent years have found that some inorganic ions are essential for the functioning of many enzymatic systems while others act as poisons. Thus, magnesium ion is an activator in the phosphorylation of glucose necessary for the synthesis of starch in many plants, while fluoride acts as a poison in the carbohydrate metabolism of some forms of life, preventing oxidation of glucose. If the inorganic constituents change sufficiently to influence enzyme systems in the plant, then the concentration of some of the organic constituents is likely to vary. A significant result of this analytical work might be provision of a clue to improvement of fertilization practices which would eliminate certain non-sucrose impurities or increase the amount of desirable by-products.

Summary

Preliminary analyses for acids in sugar-beet diffusion juices from four growing areas have been presented. Variation in concentration of all the organic compounds investigated, except citric acid, is marked and will ininfluence attemps at recovery of by-products.

Methods of fractionating acids on ion exchange resins in the base or chloride form have been described.

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ACKNOWLEDGMENT—The authors are grateful for the cooperation of Miss Neva Snell for the amino acid analyses of Miss Elizabeth McComb for phosphate and some of the oxalates, E. F. Potter for chloride and some of the citrates, Miss Barbara Washauer for the sulfate analyses, F. T. Jones for the crystallographic identification of mucic acid, K. T. Palmer for the X-ray diffration identification of lactic and l-malic acids, and members of the sugar beet industry for generous supplies of processing liquors.

Fluid Clutch Motor-Driven Centrifugals

JOSEPH HERTRICH[1]

General

The Fluid Clutch motor is applied on a centrifugal in the same manner as a direct connected electric motor.

Schematically, the drive consists of an electric motor connected to the centrifugal by means of a fluid clutch. The motor is always running at top speed and the power connection is made or broken by filling or emptying the fluid clutch. The rate of power transmission is determined by the quantity of oil in the fluid clutch. The quantity of oil at any time circulating in the clutch is controlled by suitable outside controls, such as torque, speed and filling controls.

The application of slip clutches on centrifugals is well known. In certain characteristics the fluid clutch compares with the centrifugal type friction clutch, in other characteristics it deviates so far from the friction clutch that in practical application the results are quite different. The fluid clutch lends itself particularly for high speeds and high power transmission.

Principle of Operation and Characteristics of Fluid Clutch

The Fluid Clutch consists of an impeller which is connected to the drive motor (equivalent of a centrifugal pump) and the runner which is connected to the centrifugal (equivalent of a turbine) which are operating concentrically and adjacent.

When oil is introduced into the coupling the impeller, which is rotating at a relatively constant speed, imparts a velocity to the oil which is then transferred to the slower revolving runner inside of which some of the oil velocity is absorbed. This results in an oil vortex inside the coupling where the oil continuously enters the impeller near the center at slow velocity and leaves it near the circumference at high velocity. It then enters the runner near the circumference at high velocity and leaves the runner at low velocity near the center. This change in velocity of the oil entails a change in kinetic energy of the oil which is proportional to the square of the velocity change. Consequently the impeller imparts kinetic energy to the oil while the runner absorbs kinetic energy from the oil. About 90% or more of the power is transmitted by exchange of kinetic energy while 10% or less is transmitted by hydraulic friction. The amount of power transmitted then depends on the amount of oil circulating in the coupling (rate of filling) and the vortex velocity which changes with the slip in the coupling.

The characteristics of a fluid clutch are generally as follows:

a) The torque capacity varies approximately in proportion to the square of the impeller speed.
b) The torque capacity varies, within certain limits, in proportion with the slip, that is, the difference in speed between impeller and runner.

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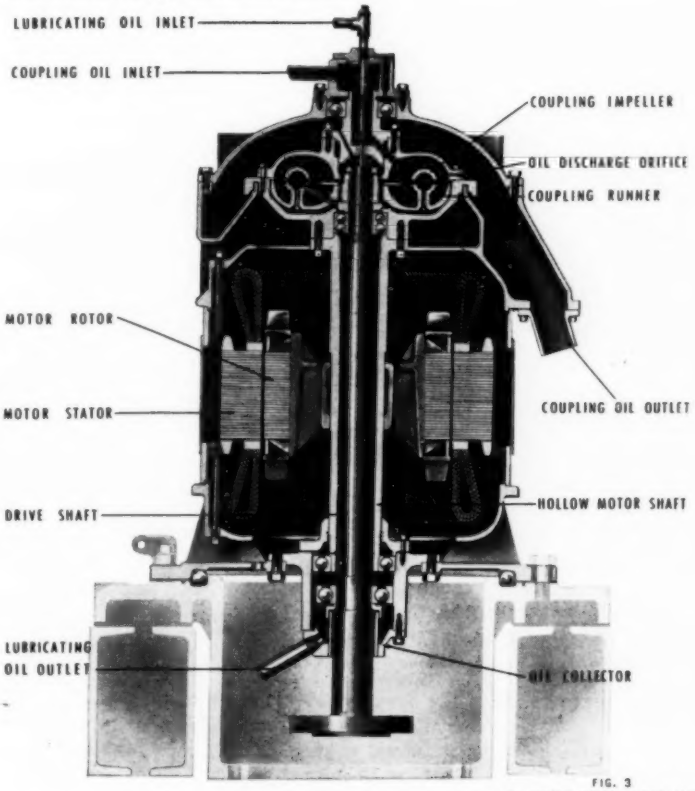
[1] Research Engineer, the Western States Machine Co., Hamilton, Ohio.

c) The input torque and output torque are equal.
d) The energy lost in the coupling is proportional to the slip. This energy is absorbed as heat by the oil which in turn must be cooled.

Design Features

Fig. 3 shows a section through a vertical fluid clutch motor. The unit with the drive shaft extending downwards connects to the centrifugal head in the same manner as a direct-connected vertical motor. The fluid clutch arranged above the hollow shaft motor makes a compact design possible with good bearing supports for both shafts.



40 HP FLUID CLUTCH MOTOR

FIG. 3
THE WESTERN STATES MACHINE COMPANY
HAMILTON, OHIO

The machine is composed of:

a) The stationary unit—comprising motor stator, lower end shield with flanged base, upper end shield with oil collecting chamber, upper endshield cover and bearing cartridges.
b) The primary revolving unit — comprising the motor rotor

mounted on the hollow shaft, the coupling housing and fan bolted to the hollow shaft, the impeller and the two supporting ball bearings.

c) The secondary revolving unit composed of the runner and flanged drive shaft and the supporting ball and roller bearings.

The motor is a conventional single speed squirrel cage motor with standard windings and power characteristics. It is started by a reduced voltage or an across the line starter and then runs continuously at high speed. The heat produced in the motor is comparable to the heat produced in any standard motor under full load. The motor is cooled by the air flow produced by the fan on the coupling housing.

The oil is introduced into the clutch through the oil inlet pipe on top of the unit. While the clutch is filled with oil, there is a continuous stream discharged through four discharge orifices in the impeller which collects in the oil collector housing from where it flows to the oil cooler.

The required filling of the coupling is obtained by the regulated oil flow into the coupling as determined by the outside controls.

All bearings are lubricated by a continuous oil flow through the lubricating oil inlet line on top of the motor. The same oil supply is used for the lubrication and for the power transmission. Part of the lubricating oil discharges through the lubricating oil outlet pipe below the lower bearings.

Oil Flow Controls

The oil flow to the fluid clutch is controlled as follows:

1) Manually by the operator to start and stop the machine and to regulate the discharge speed.
2) By the automatic cycle control which shuts the oil off at the end of the drying cycle and applies the brake.
3) By the torque control which regulates the oil flow so as to obtain the desired acceleration torque.
4) By the speed control which shuts the oil supply off at a desired speed below the maximum speed of the unit.

The machine can be furnished with manual control only, eliminating the other 3 controls where they are not required.

Manual Control

The manual control consists of an oil solenoid valve in the oil supply line which is controlled by a master switch which interlocks the oil valve with the brake so that the fluid clutch and brake can not be energized at the same time. The master switch has three positions, namely "Brake," "Off" and "Run."

Automatic Control

The automatic control is added to the manual control by adding one or more electric timers which time all desired functions such as "Washing," "Separator Trip," "Stop" and any other desired timed function.

The master switch now has four positions, namely, "Brake," "Off," "Plow" and "Run." In "Plow" position the oil solenoid valve is energized, thus engaging the fluid clutch. In "Run" position the electric timer is also energized and times the automatic functions of the cycle. This timer controls the application of the brake at which time also the oil solenoid valve is closed and the fluid clutch disengaged.

Speed Control

Two types of controls are used:

a) The differential governor type for fixed top speed.

b) The oil governor type for variable top speed.

Fig. 4a shows a section through the differential type governor, which was designed especially for this application.

The normally closed limit switch of the governor is wired into the

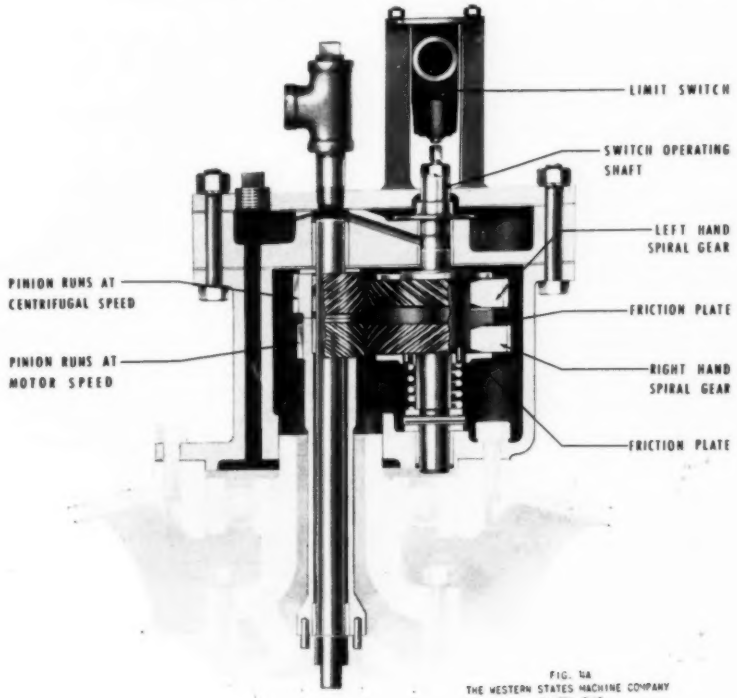


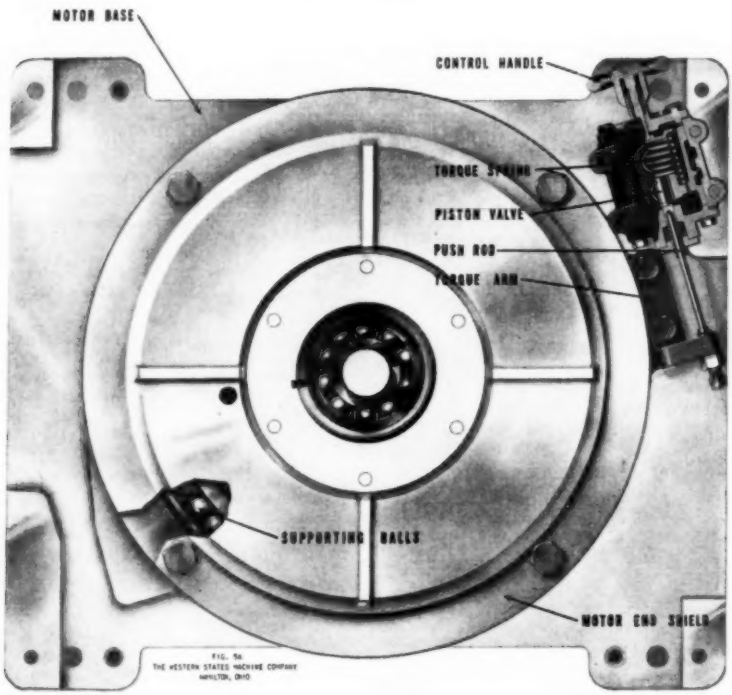
FIG. 4A
THE WESTERN STATES MACHINE COMPANY
HAMILTON, OHIO

SPEED CONTROL UNIT

control circuit of the oil solenoid valve. The switch is operated by an axially shiftable gear assembly, consisting of a shaft with a right hand and a left hand spiral gear, held together by spring and washers in such a way that there is some frictional resistance to the relative rotation of the two gears. These gears are driven by left and right hand pinions which are connected to the motor shaft and centrifugal shafts respectively. The gear ratios selected determine the speed of the centrifugal. The spiral gears produce an end thrust either downward or upward, depending on whether the right hand or the left hand spiral gear is driven faster. As long as the centrifugal operates below the controlled speed the thrust is downward. When the centrifugal operates at the controlled speed, there is no thrust because both

gears are driven at the same speed. When the centrifugal operates above controlled speed the thrust is reversed to upward so that now the shaft moves up, trips the limit switch and shuts off the oil supply to the fluid clutch.

The machine now coasts until the speed gets below controlled speed and the oil solenoid valve is again energized.



The oil governor type speed control consists essentially of the control pump driven at the speed of the centrifugal which pumps oil at the rate of its driven speed. This oil is discharged through an adjustable orifice in a speed control valve. For a given setting of the control valve the oil pressure will then vary with the square of the speed of the machine.

This oil pressure is used to operate a diaphragm-operated oil valve which is inserted in the oil supply line in series with the oil solenoid valve. With this speed control any speed from 300 RPM to top speed can be selected merely by turning the control valve.

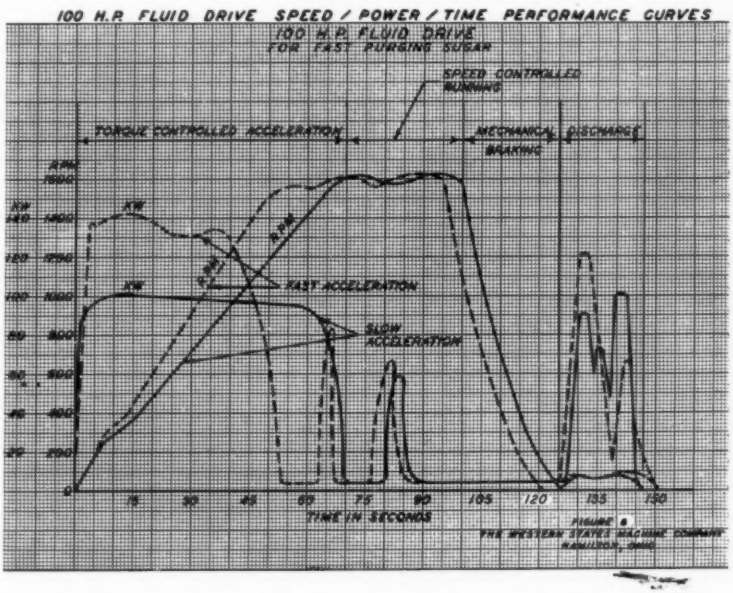
The oil governor type of speed control is used in the chemical industry where variable speeds are many times required.

For the sugar industry where high production is required and the speed

is generally fixed for a given product the differential type governor is used. This insures a definite top speed of all machines in a battery which can not be altered without introducing new gears in the speed control.

Torque Control

The power transmitted by the fluid clutch is controlled by the torque



control valve of which Fig. 5a shows a horizontal section through the center. This valve is inserted in the oil supply line in series with the oil solenoid valve. It is normally held open by an adjustable spring and is closed by the torque reaction of the motor in the following manner:

The motor is supported on a row of balls and is free to swivel within a small arc. The torque valve is bolted to the fixed motor base and is connected to the movable motor frame by an arm and push rod in such a way that the spring in the torque valve pushes the motor frame in the direction of rotation. When oil is introduced into the coupling the torque increases until the torque reaction on the frame is strong enough to compress the spring and partly close the torque valve. The stator and valve will automatically assume the position in which the oil flow to the coupling is sufficient to produce the torque for which the torque spring has been adjusted. A handle is provided on the torque valve for regulating the torque by changing the spring pressure.

Sizes

Fluid Clutch motors have been made in ratings of 30 HP, 40 HP, 50 HP, 60 HP, 75 HP, 100HP and 125 HP and are operating at speeds from 1,400

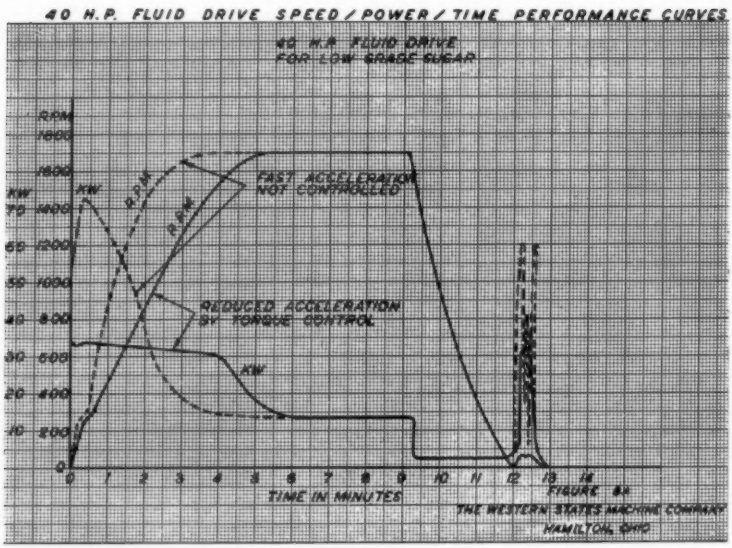


FIGURE 8A

to 2,200 RPM. The speeds above 1,800 RPM are obtained by a stepup of the frequency.

Advantages

Some of the advantages of the fluid drives are:

1) **Smooth power connection between motor and centrifugals resulting in lower stresses in the working parts.**
2) **Continuously running electric motor eliminating high starting stresses in the motor and violent fluctuations in the power supply lines. Resulting in longer life of the motor, starter and other machinery.**
3) **Cool running motors insuring a long life of the motor winding without using special insulating materials.**
4) **Motors are of standard type, using standardized ratings.**
5) **With torque and speed control available the units can be selected for the best process advantages. The acceleration rate can be altered to suit requirements.**
6) **The torque control produces an almost straight line acceleration and a constant power pull from the line during acceleration. High power peaks are eliminated.**

Power and Speed Curves

Fig. 8 shows two sets of power and speed curves taken on a 100-HP Fluid Drive with torque control and differential speed control driving a 40" x 24" x 6" centrifugal at a top speed of 1,600 RPM, processing white sugar in a beet sugar factory.

The two curves were picked out of a series of graphs made with different torque control settings. Note the constant power pull during acceleration and the corresponding straight line acceleration.

With the first setting the motor pulls an average of 135 KW and accelerates the machine to 1,600 RPM in 50 seconds. The second torque setting produces a power pull of approximately 100 KW and accelerates the machine to 1,600 RPM in 67 seconds.

Note that the top speed is maintained by small intermittent power impulses, resulting in a slightly wavy speed curve.

Fig. 8a shows two sets of power and speed curves taken from a series of test graphs made on 40-HP fluid drives with torque controls (no speed control) driving 40" x 24" x 6" low grade centrifugals in a beet sugar factory.

The first curve shows the fastest acceleration rate with the maximum torque setting. The machine reaches 1,600 RPM in 2¼ minutes and accelerates slowly from there on up. Note that the torque control valve is only active for approximately ½ minute and that from then on the power capacity of the coupling is less than the torque setting. The maximum power pulled is 73 KW.

The second set of curves indicates an acceleration to 1,600 RPM in approximately 4 minutes with a steady power pull of about 32 KW for the greater part of the acceleration period.

In cases where a still longer acceleration is desired it is found that the torque produced is not enough for satisfactory discharging operation. An additional oil valve is then used to bypass the torque control valve.

Conclusion

It is not the purpose of this discussion to convey to you a conviction that this type of centrifugal drive is superior to all others. Rather, we attempted merely to give you some idea of the design and construction with the resulting operating characteristics.

We manufacture five different types of centrifugal drives and there are conditions prevailing at different factories which can properly indicate each one of these drives as superior for a specific situation.

The Oliver Morton Battery

W. W. CONNER[1]

The early background of the Oliver Morton battery began in 1935 at our Manteca factory.

During the 1935 campaign we began an investigation of continuous diffusion. Our Mr. Winslow was in charge of the work and one of his helpers was Mr. Morton. This formal investigation was more or less discontinued after one year, but the principles developed in this work continued to fascinate Morton, and on his own time he continued to work on the idea of a continuous battery. In 1947 he convinced the Oliver Filter Company that he had a practical solution, and they entered into an agreement to develop it. During the 1948 campaign a small pilot size continuous battery, consisting of 12 cells, was installed for test purposes at our Woodland factory.

In description, the Morton battery is a series of "U"-shaped tanks set on a slope. Each cell is equipped with a scroll to convey the cossettes through the tank. On the discharge end of the scroll is a lifting device for transferring the cossettes to the next higher cell. The transfer mechanism consists of banks of fingers, attached to the rotating shaft, which pass through stationary grid bars. In the end of each cell, adjacent to the transfer mechanism, is a screen for separating the juice from the cossettes. Thus, the cossettes go from cell to cell up the slope and the water flows from cell to cell down the slope. In principle, the Morton battery is a series of tanks connected to allow a flow of juice and in which the cossettes are immersed, drained, and moved up to the next cell counter-current to the flow of juice.

The cells of the pilot unit were 4 ft. in diameter ("U" section) and 8 ft. long. The unit of 12 cells was operated throughout the 1948 campaign, and many series of tests with rates as high as 700 tons per day were made.

From the results of these tests it was our opinion that the Morton battery was a practical continuous battery. Mechanically it was simple and the rate of diffusion appeared to be satisfactory.

On the strength of the pilot plant test, Spreckels Sugar Company contracted for two commercial-sized batteries, which were installed for the 1949 campaign. One was a 24-cell unit installed at the Woodland factory and the other a 28-cell unit installed at the Salinas factory.

The cells in each unit were the same, except that the number of cells was different. They were 7 ft. in diameter ("U" section) and 12½ ft. long. Each cell contains approximately 400 cu. ft. at the working level. Except for the screens in the first 6 cells, which were Everdur, the construction was all steel. Twelve of the cells in the Woodland battery (Nos. 1, 2, 3, 4, 5, 6, 10, 14, 18, 22, 23, 24) and thirteen of the cells in the Salinas battery (Nos. 1, 2, 3, 4, 5, 6, 10, 14, 18, 22, 26, 27, 28) were equipped with steam jackets to supply the heat. Both batteries were fed by means of a weightometer belt. The rate of cossette feed was controlled by varying the rotating speed of the cutters.

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[1] Spreckels Sugar Company.

Two cell units were driven by one motor. The speed of the motors was varied by varying the cycle frequency.

By means of ratio controllers it was possible to have the weight of beets on the belt control the speed of rotation of the cells and the rate of water addition.

In the design of the factory-sized installations we planned about a

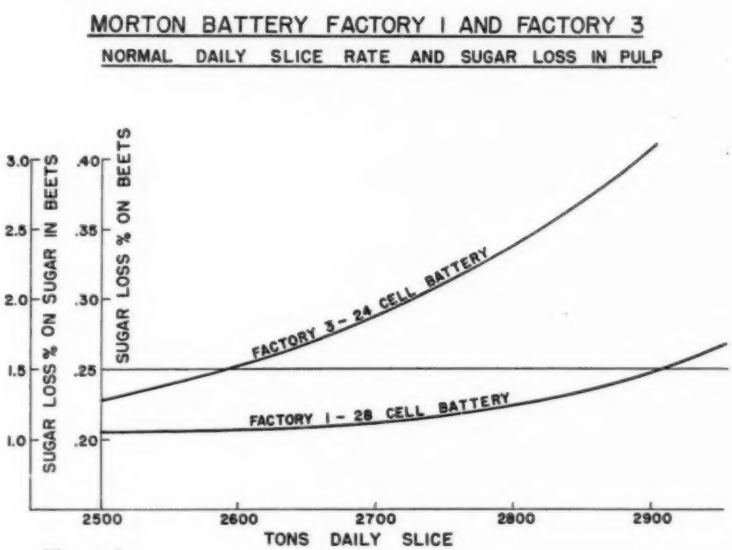

Figure 1.

2,700-ton-per-day capacity at Woodland and about 3,000 tons per day at Salinas.

It takes good estimates and also some good luck to go from the design of a pilot plant size to commercial size and although we had good pilot plant testing, we miscalculated a few points in the factory size. Consequently we had some growing pains during the first year's operation.

At a rate of 2,000 tons per day or perhaps slightly more, and with a draft up to 130, operation was quite good.

However, this was below the capacity needed and we tried continually to operate to the capacity of the house, which was about 2,700 tons for Woodland and 3,000 tons for Salinas, and when we tried to operate at these capacities we began to have trouble.

First, the connections between the cells for juice flow were not large enough to allow sufficient draft. At the desired slice rates a draft of from 115 to 117 was as much as the juice lines would carry.

Second, when we crowded the slicing rate the screens began to blind, and this was our most difficult problem. The blinding was apparently not

due to obstruction in the screen perforations, but rather a layer of cossettes held flat against the screen.

We made several minor mechanical changes which improved the operation appreciably and there were more that we would have liked to have made, but the pressure of the campaign would not permit a shutdown for such alterations.

While during this first operating season we cannot say that we solved the problem of screen blinding at slicing rates in the neighborhood of 2,700 tons, we do think this difficulty can be corrected. After another campaign we shall know the possibilities better.

Total beets processed through the Woodland battery were 295,172 tons at an average daily rate of 2,419 tons.

Total beets processed through the Salinas battery were 268,823 tons at a daily average of 2,512 tons.

In Figure 1 two curves are shown, which are plotted from operating data as sugar loss against rate of slice. The draft was for practical purposes constant, varying only from approximately 120 at the lower rates to 117 at the higher rates. These curves do not show slicing rates below 2,500 tons. For the limited number of days that we operated at about 2,000 tons (this was at the Woodland plant) the pulp loss averaged .14 with 125 draft.

During the first 75 days of the campaign, or up until the first rains, there was no noticeable dip in the pH curve through the battery. Normally the water cell was about 8.9 pH and the raw juice was about 6.0 pH. After the rains, however, there appeared at times a dip to about 5.5 pH, running from as high as No. 20 cell to as low as No. 8 cell. At such times we used formaldehyde. Such use was not excessive, however, as we used a total of only 235 gallons at the Woodland factory and about 90 gallons at the Salinas factory.

All cells which operated normally at a pH under 7 showed some corrosion. The cells with the lower pH showed the greater amount and for the most part it was in the areas which were scrubbed by the travel of the cossettes. Apparently any protective oxide was abraded off by the continual wiping action of the cossettes and this gave a clean bright surface upon which the low pH juice acted. The only exception to this was the area covered by the steam chest on the first few cells. Here the heat caused a coagulation and a typical raw juice scale formed on the heating surface. It was quite thin and never built up enough to be noticeable to the heat transfer.

The Everdur screens in the first six cells were not attacked nor were the stainless steel cap screws used in the construction of the transfer mechanism.

Generally speaking, even with the troublesome growing pains experienced this first year, we are enthusiastic about the possibilities of the Oliver-Morton battery.

Beet Receiving and Storage

Improving Screens for Trash and Dirt Elimination in Sugar Beet Receiving Equipment

READ A. WILKINSON[1]

Purpose of Screens

Modern techniques of the beet sugar industry necessitate a marked decrease in the amount of dirt and trash entering both processing plants and storage piles. Such reduction can only be accomplished through the development of more efficient screens.

Location of Screens

The most efficient trash and dirt removal equipment to date is complicated, expensive, and heavy. It does not, therefore, adapt itself readily to small comparatively inexpensive mobile equipment suitable to average field conditions. Consequently, it is logical to conclude that, in order to satisfy both grower and processor demands, an intermediate station, for the express purpose of intensifying an all out effort for trash removal, be established. Without a doubt the present receiving station is the most practical location. At such central locations the necessary equipment can be installed to both clean the beets for the processor and return the trash with the haulers to the field, where such return is permissible.

Field Causes and Partial Prevention for Increased Trash

The advent of mechanical harvesting has, in many cases, resulted in increased trash delivered, due to inexperienced operators, poor adaptation of type of machines, overloaded screening systems of harvesters, and adverse harvesting conditions. These difficulties have been minimized in south Idaho by extensive use of the "beater topper," substitution of "short" rienks for screens in loaders and the use of picking belts on International harvesters. General field cleanliness has also contributed much to reduce the trash burden.

In spite of the above accomplishment and because of its limitations, it has still been necessary to maintain, or seek for, extremely efficient elimination at the receiving stations.

Design Considerations

In an attempt to make changes, other considerations manifest themselves. They are listed as follows: The prevention of—1. Small beet loss; 2. Excessive breakage of beets; 3. Excessive gashing and bruising; 4. Plugging of machine from mud; 5. Jamming of maching from rocks. These conditions had to be met without affecting capacity.

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[1] Agricultural Engineer of the Amalgamated Sugar Company.

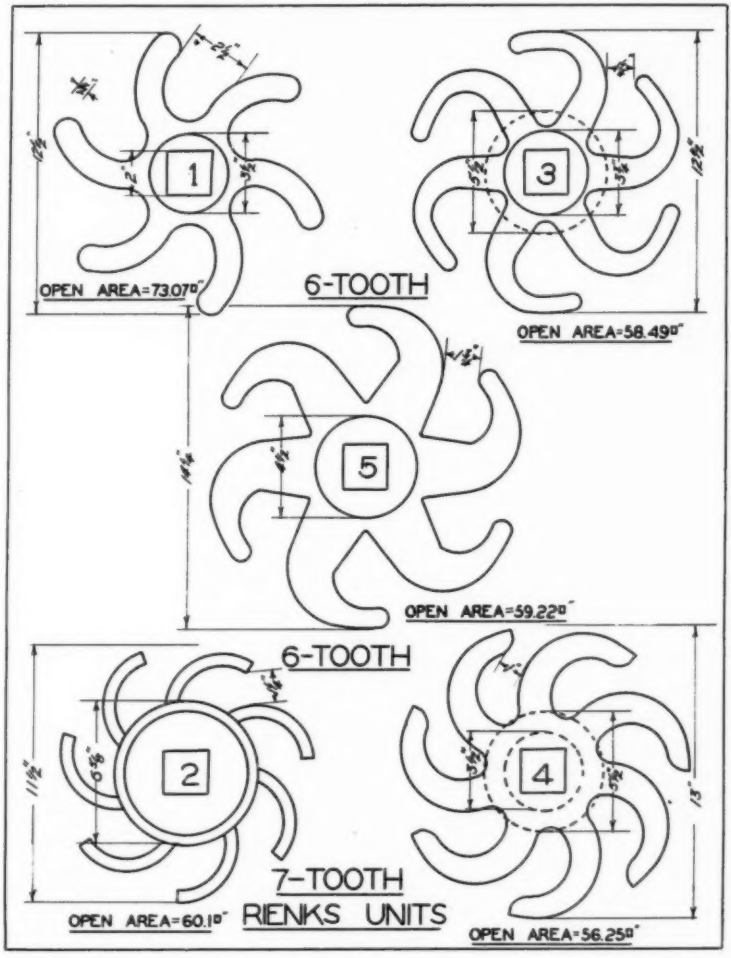

Figure 1.

Progress of Screen Development

The following is a brief resume of the progress in screen development to date, which was done with the cooperation of the Ogden Iron Works of Ogden, Utah.

1. Bar Type Screens: To facilitate trash elimination in this common type screen a reverse screen chain was placed at a 45° angle between the upper and lower shaker chains as illustrated in the "Early Screen Arrange-

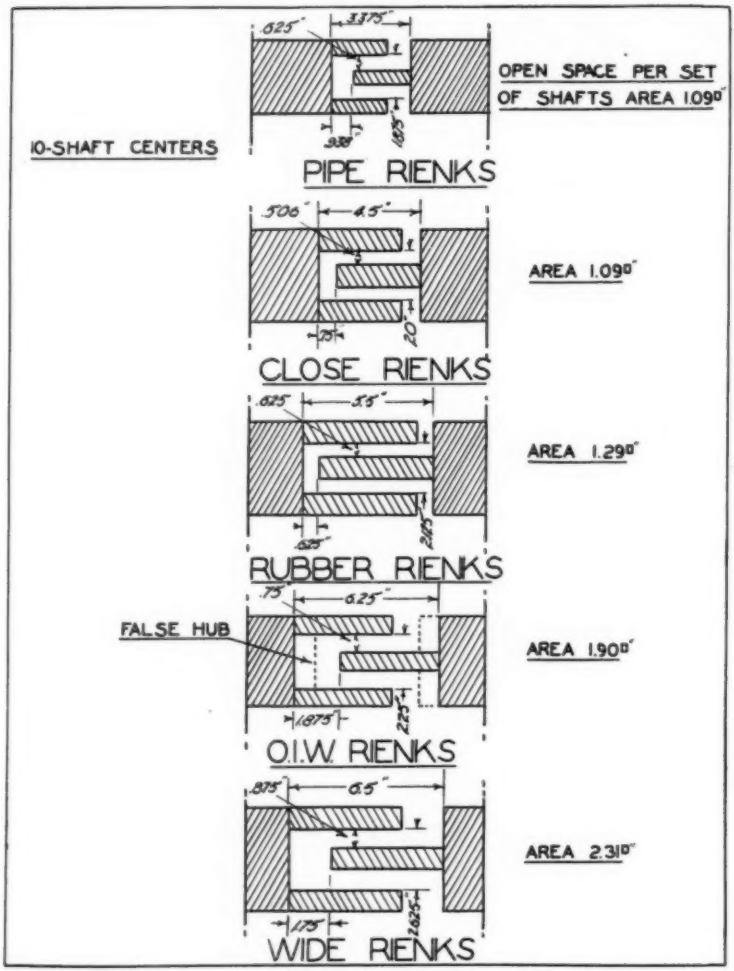

Figure 2.

ment." The lineal speed of these reverse chains was approximately 250 feet per minute. In order to increase their trash carrying capacity, the following changes were made: the angle of chain was reduced to approximately 30°, cleats were attached to the screen bars; reverse chains were divided into two sections, upper and lower, with lineal speeds reduced to approximately 65 feet per minute; a blower was installed to jet air upward over the top of the reverse chain to aid in holding the leaves to the chain until they were

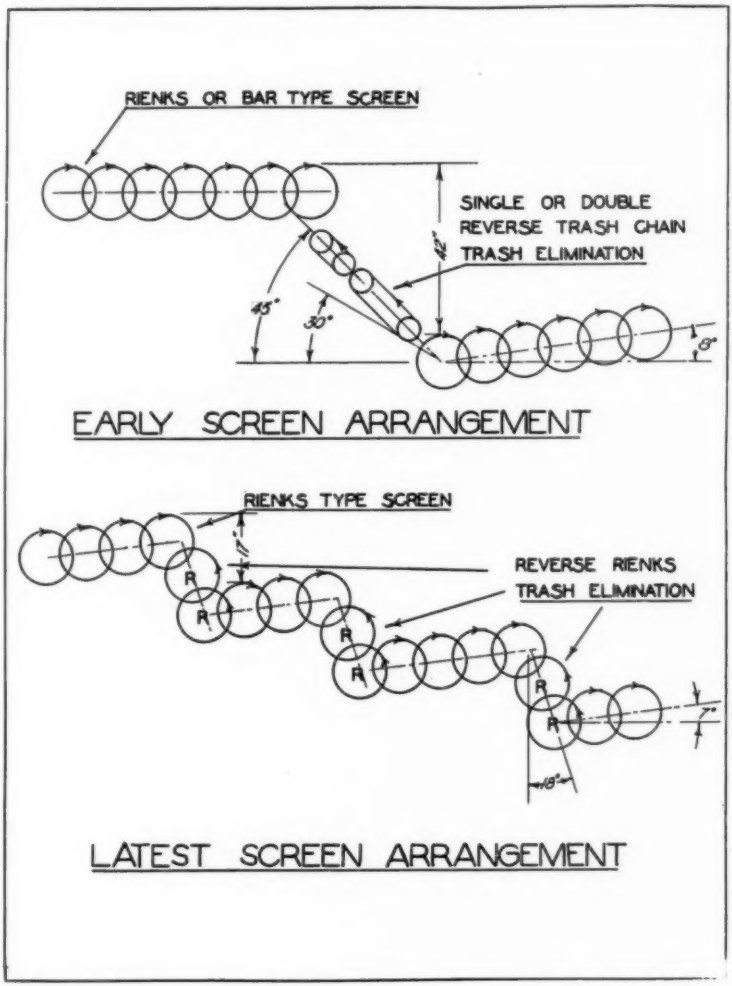

Figure 3.

discharged into the return dirt; and the flow of beets over the screen was controlled, so that a longer cleaning period could be given them if they contained excessive trash or dirt.

2. **Eccentric Ring Type Screen:** Trash elimination was again attempted by a split reverse screen chain placed at a 45° angle as shown in **Figure 3.**

Table 1.—Showing Screen Comparison Based Upon Bar Type Tripple Screen Unit.

Screen Area											
Total Open	Max. Open	Screen Type	Trash Separation	Load Return	Small Beet Return	Tail and Chip Return	Trash and Leave Return	Dirt Return	Tare	Stops for Rocks	Remarks
11.99	.938	7-tooth pipe rienks	Reverse rienks	Same	Same	Same	Same	Same	Same	Large Incr.	Not efficient in mud
12.01	.750	7-tooth 7/8" plate—close spaced rienks	Reverse chain	Same	Same	Same	Same	Same	Incr.	Small Incr.	Not efficient in mud—excessive drops
14.22	1.000	6-tooth—13 shaft rubber rienks	Reverse chain	Incr.	Incr.	Incr.	Same	Incr.	Less	Less	Not affected by mud or rocks—excessive drops
15.48	1.000	6-tooth 19 shaft rubber rienks	Reverse rienks	Incr.	Incr.	Incr.	Incr.	Incr.	Less	Less	Not affected by mud or rocks—excessive drops
19.15	.875	5/8" bars @ 1.5" on cent. bar screen	Reverse chain	Base	Base	Base	Base	Base	Base	Base	
20.93	1.875	6-tooth—13 shaft —cast steel rienks	Reverse chain	Large Incr.	Large Incr.	Large Incr.	Same	Small Incr.	Incr.	Large Incr.	Mud build up on hubs—excessive drops
21.89	2.000	6-tooth—3/4" pl. rienks	Reverse rienks	Large Incr.	Large Incr.	Large Incr	Incr.	Large Incr.	Less	Incr.	Mud build up on hubs—excessive drops
22.26	1.000	solid ring eccentric	Reverse chain	Same	Same	Same	Same	Same	Same	Incr.	Not efficient in mud—excessive drops
22.86	1.875	6-tooth—19 shaft —cast steel rienks	Reverse rienks	Large Incr.	Large Incr.	Large Incr.	Incr.	Large Incr.	Less	Large Incr.	Mud build up on hubs—excessive drops
25.36	1.750	7-tooth—7/8" plate wide spaced rienks	Reverse rienks	Largest Incr.	Largest Incr.	Large Incr.	Incr.	Large Incr.	Less	Incr.	Mud build up on hubs—excessive drops

Through angle manipulation, as was explained previously, increased trash separation resulted but the amount was insufficient and a change from the eccentric screen to a standard rienks became necessary some time later. The six-tooth elements were of ¾-inch thick cast steel (No. 3 in Figure 1) spaced three inches on centers having 3¾-inch hub diameters and located upon shafts spaced ten inches apart.

Observation indicated increased dirt and clod separation but loss in small beets, breakage of beets, numerous stops occurring from rocks and mud building up on hubs offsetting all progress gained.

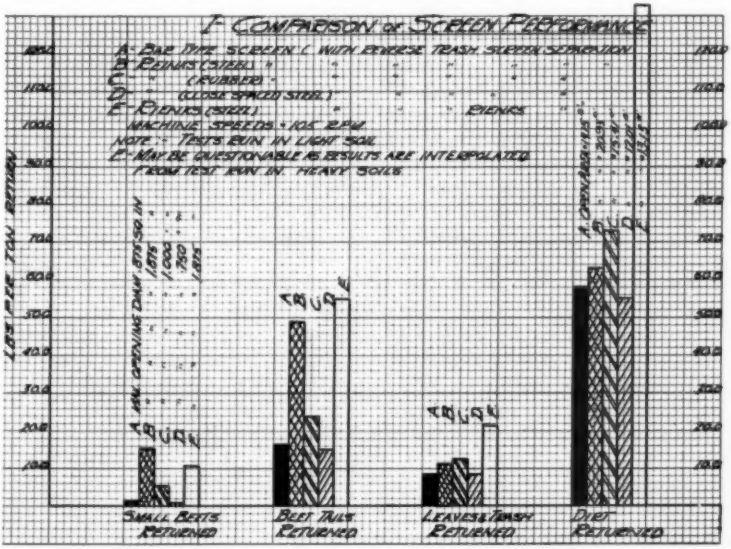

Figure 4. Information from the above data was averaged and plotted upon this graph presenting the resulting comparison of screen performance. From an analysis of this information the following conclusions were derived: the closed type rienks and the bar type screens perform about the same with regard to screening ability; the standard spaced cast steel rienks screens, although eliminating a large amount of dirt in dry conditions, are objectionable because of excessive beet loss; trash elimination is dependent upon the removal system used and any variation in type of screen does not effect much change. The reverse rienks method of elimination separates a larger amount of trash from the beets; rubber rienks elements provide greater possibilities for future screens.

Attempts to relieve the above drawbacks consisted first of a change in speeds varying from a high of 150 R.P.M. to a low of 60 R.P.M. It was found that at approximately 100 R.P.M. the capacity was maintained with a minimum loss of small beets and breakage. Second, in order to further reduce the loss of small beets by closing of screen, false hubs of 5½" outside diameter were inserted, as shown by dotted insertions upon the illustrations in Figure 1.

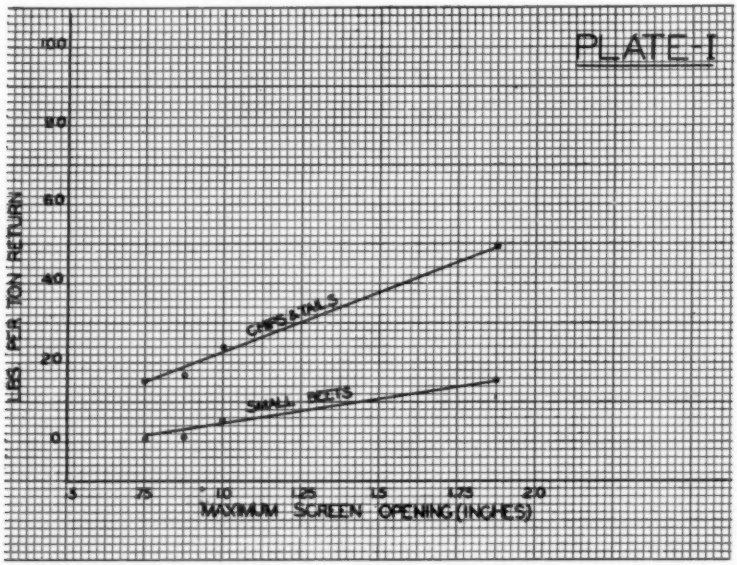

Figure 5. The relationship of small beet and beet tail loss to maximum screen opening is shown here with the expected increase in loss as the openings extend beyond .75 inch.

3. [2] **Standard Rienks Type Screen:** The latest piler unit was originally equipped with a rienks screen constructed of seven ⅝-inch round bar curved teeth welded in 2½-inch rows to 6⅝-inch outside diameter pipe cylinders (No. 2 in Figure 1) which were mounted on shafts ten inches apart. Trash elimination was accomplished through reversing the direction of rotation of three sets of two rolls located at each of three abrupt short drops. This method of trash elimination is shown in the elevation entitled "Latest Screen Arrangement."

Separation by this screen was quite satisfactory under ideal conditions with a minimum beet loss and breakage. However, under adverse conditions

[2] This type screen was originally developed by George Rienks, formerly of the Great Western Sugar Company, in 1929 and all adaptations since have been identified by his name.

mud build up and wedging rocks reduced the efficiency of this machine to such an extent that it was readily decided to change to two different types of rienks elements, namely, a six-tooth ¾-inch plate and six-tooth cast steel spaced three inches on centers as described above and illustrated by Nos. 1 and 3 in Figure 1. Although the above undesirable conditions improved, the problem of excessive beet loss and breakage again developed.

The screens in this piling unit were installed originally upon a seven degree back slope to retard partially the flow of beets for increased cleaning.

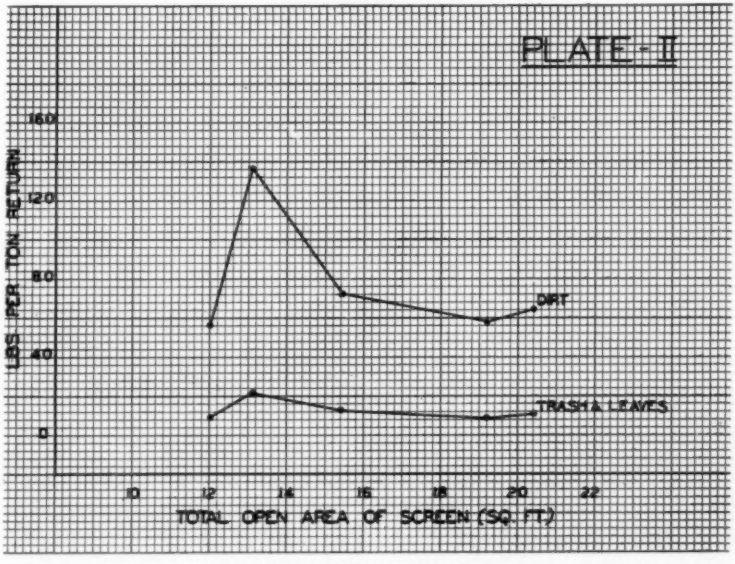

Figure 6. Only a small change is indicated by this curve in the dirt and trash separation within the range of total open area facilitated by the screens operating in this test. Therefore, in general it may be concluded that the amount of elimination depends upon the type of screen rather than the amount of open area available.

This proved to be satisfactory as long as the length of screen was short, but if it extended beyond five rolls a stagnation of beet flow resulted in a churning action just below the reverse shafts and the capacity of the machine was impaired. Changes in shaft speed had no effect upon this condition and not until the back slope was reduced was the capacity increased.

4. Trials Involving Screen Elements and Element Spacing: Analysis and comparison of screen openings (as shown in accompanying illustration) necessary to eliminate beet loss and still maintain adequate capacity were made. A part of this analysis consisted in determining the upper and lower limits adaptable to existing local conditions. This was accomplished through

the construction and trial of two test screens. One was built establishing a maximum spacing. It was composed of 7/8-inch plate seven-tooth elements spaced 3½-inch centers having 3½-inch outside hub diameter (No. 4 in Figure 1). A seven-tooth element was tried because previous studies indicated that a closer distance between tooth points of each individual element was desirable.

Field trials indicated that such a spacing left too great an open area for small beet loss and no doubt exceeded the maximum point desired. Trash and dirt separation was exceptionally good but was offset by the beet loss.

A calculated minimum spacing of this same type element was then set up so that they were centered at 2¾ inches apart with hubs of 5½-inch outside diameter. From field trials of this screen it was found that beet loss and breakage was very small. Little or no rock trouble occurred; however, there was no increase in trash and dirt separation over the bar type screen. Mud accumulation on both hubs and between individual element teeth was excessive. From the above results it was concluded that screen element spacing should approach 3 inches.

5. Rubber Screen Development. After preliminary tests a 70 durometer, six-tooth element (No. 5 Figure 1), one inch thick and 14½ inches in diameter was molded, having a hub of 4½ inches outside diameter. These were spaced three inches on centers upon the shafts so that their location would relive any congestion due to rocks wedging between two steel elements. Three patterns were tried: One in which there were alternating clusters of three rubber and two steel upon the same shaft, another pattern consisting of alternate shafts complete with rubber and steel, the remaining pattern involving complete rubber on all shafts.

The results from these trials were extremely satisfactory as rock wedging was completely eliminated and mud accumulation on hubs became almost negligible. Greater dirt elimination prevailed due to the fact the screen did not close from a mud build up upon the hubs. The change in spacing reduced the small beet loss to a minimum and beet breakage upon the rubber elements was reduced considerably.

After many trials it was realized that a trash removal system separate from the rienks dirt screen was necessary. An attempt to develop such trash separation is therefore in progress. It consists of tests made with four-inch pipe trash rolls which it is hoped will follow a reinks-type screen. The operation of this unit under ideal conditions has proven to be quite satisfactory; however, there are many undesirable features to be overcome.

In order to facilitate ease in comparing the screens just discussed Table 1 is included.

Field Trials of Operating Screens

To obtain a definite comparison between several types of beet piler screens and learn more of their characteristics a screen test was run. It consisted of hauling beets from one field, harvested by the same mechanical harvester in identical soil type, over five different types of screens alternating

from one to another. In such manner it was hoped to reduce the influence of the varying factors upon the comparative results. All weights and tare for each load were recorded. The return dirt was screened and separation of marketable beets, beet tails, leaves and trash, and dirt was made. Weights of each were taken and recorded. An air dry moisture test was run on each load and the moisture present recorded.

Results of trials are given in Figures 4, 5, 6 and 7.

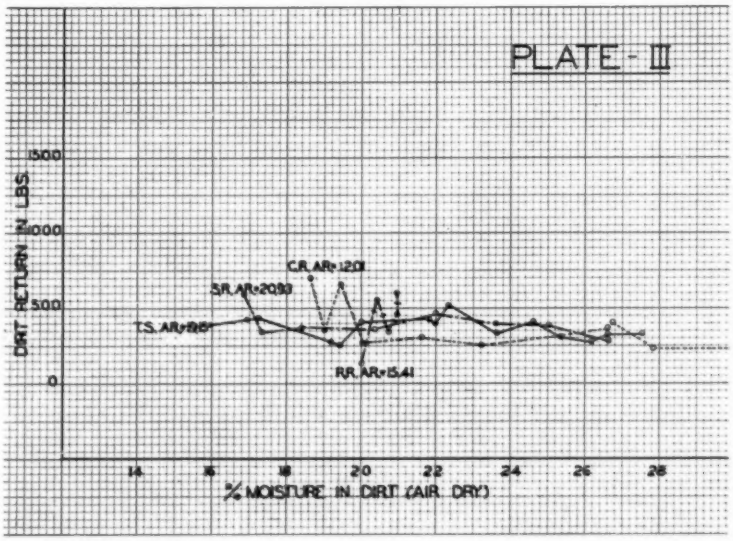

Figure 7. Effect of moisture upon dirt return is shown upon this plate. It can be noted that there is a reduction for all types of screens used except that composed of rubber rienks elements. This latter condition is due to little or no mud build up on the hubs from the flexing quality of the rubber. Since this screen test was run in extremely light soil the actual reduction in return dirt is not as great as would be expected.

SUMMATION AND CONCLUSION

1. **Advancing sugar beet mechanization and necessity for a lengthened storage period of piled beets necessitates more efficient and increased dirt and trash separation.**

2. **From both a practical and economical standpoint the location for intensified trash elimination is at the receiving stations upon industrial equipment.**

3. **Development of highly efficient screens involves the consideration of many problems in connection with increased capacity such as small beet loss, excessive beet damage and mud and rock interference.**

4. Inefficiency of the bar type screen, with reverse chain trash elimination, has necessitated much additional investigation which at present has centralized upon an efficient type of rienks screen with either a reverse rotation trash separation or other more efficient means.

5. A three year trial operation in southern Idaho of rienks type screens has resulted in the formulation of the following conclusions for more efficient separation, namely, (a) speeds should not be excessive but should approach 100 R.P.M.; (b) the fall of beets should be reduced to a minimum; (c) separation of foreign materials from beets should be accomplished in two stages, first dirt separation, second trash elimination; (d) the greatest possible total open area should be allowed in screen design providing that one dimension of each individual opening is not in excess of .75 to 1.00 inch. Open area is not, however, a definite criterion as to trash removal; (e) individual rienks element diameters of 13 and 14 inches have proven best at the above speeds, and should be so constructed as to incorporate in plain view a design allowing as much open area between teeth as structurally possible; (f) a maximum distance of 1¼ inches between the following edge of preceding and leading edge of the following teeth was found most satisfactory for rienks elements used as, and with, reverse rotation rienks trash return units; (g) individual rienks elements should be made from a resilient material, rubber of 60 to 70 durometer proving the most satisfactory so far; (h) backsloping of rienks flights should not exceed 7° on short run and a reduction to even a level flight in case of a longer run.

6. Future development of beet receiving screens will depend largely upon the continued effort by progressive and interested groups to construct a trash remover which will not be adversely susceptible to extremely muddy and rocky receiving conditions, and will discharge a trash-free undamaged beet to storage piles.

The Molnau Sugar Beet Cleaning Screen

P. T. ROBINSON[1]

The screening unit under discussion was designed and built by Erwin P. Molnau, beet dump maintenance foreman for the Chaska, Minnesota, factory of the American Crystal Sugar Company. It was his belief that the extremely simple cleaner which he had in mind could be built at a reasonable cost, that it would be highly efficient and that it could be engineered easily to replace our many types of screening equipment, none of which was giving a satisfactory job of cleaning.

Two units were installed for the 1949 receiving season, one on a 30" silver Ogden piler, which incidentally was rebuilt into a straight line loader, resulting in the elimination of the boom, and the other on a 1936 Silver-Roberts Iron Works standard beet dump. One hundred sixty-five cars were loaded over the former and 158 cars over the latter during the receiving season. Rains of sufficient duration to stop all mechanical harvesting and lifting operations for three days occurred twice during the harvest period. On both occasions loads were received during the rain as long as growers cared to continue hauling and the screen functioned well, with no wrapping of trash or plugging with mud resulting.

Construction

The screening device consists of two sets of four substantially parallel 6" rollers six feet long. Each roller is formed from a plurality of 5/8" steel rod members and having means for rotating the rollers of the two sets in opposite directions (starting at the center of the screen) to split the flow of beets as they travel down the screen. The beets are carried laterally outwardly, while at the same time they move longitudinally down over the screen to the car. The rollers are six inches in diameter and are spaced one inch apart. The main drive is a sprocket and chain drive through a spring-loaded slip clutch. The 8 roller shafts are of 1 and 7/16" cold rolled and the head drive shaft is 1 and 11/16" with a pillow block supporting the center of the shaft. The rollers are driven by 5" steel mitre gears running in oil in a sealed housing. Bearings are mechani-seal flange cartridge type. The cleaner requires no greasing for a complete receiving season. The two outer rolls are elevated four inches to aid the longitudinal movement of the beets and are driven from the adjoining roller by diamond chain and sprocket. The outer side frame is 7" channel, the end sections are 5/16" flat iron and the drive cover is 1/8". Overall dimensions of the 8 roll screen as fabricated this year are 7'x4'10". The screen is most efficient at 150 RPM.

Summary

The screen is of simple construction. It is not a particularly costly installation. It is more efficient from the standpoint of both dirt and trash elimination than any screen we have observed. It does not break off beet tails. It does not clog or wrap. It performs satisfactorily in the mud. The screen will be manufactured by a commercial firm engaged in construction of beet receiving equipment.

[1] Manager American Crystal Sugar Company, Chaska, Minnesota.

Development and Application of an Axial Flow Trash Separator

AUSTIN ARMER[1]

The mechanical harvest of sugar beets in California has grown to such an extent that about three-fourths of the state's acreage is harvested by machine, principally Marbeet harvesters. The growth curve of mechanical harvesting has been almost paralleled by the curve of increased tare percentages of the beet-receiving stations of the Spreckels Sugar company. From an average tare percent of 3% over the years preceeding 1943, the tare percent of this company reached a high of 6.92 in 1949.

The management of the Spreckels Sugar Company as early as 1946 recognized the need for coping with the rising tide of trash delivered with the mechanically harvested beets. Discussions were held to determine the most effective method of attacking the problem. The management was agreed that the ideal situation would be to so alter mechanical harvesters as to prevent their delivery of anything but clean beets. Unfortunately, a realistic examination of the problem revealed that the mechanism of harvesters was not so much the cause of excessive trash as were the cultural habits of growers which had been created by the advent of mechanical harvest.

Figure 1. This car load of beets illustrates the extreme amount of trash delivered by mechanical harvest. Conventional screening methods are ineffective on such trash.

[1] Agricultural Engineer, Spreckels Sugar Co., Sacramento, California.

Figure 2. The pilot model of the fluted roll screen was a level bed of ten oppositely rotating rolls, 4 inches in diameter. A 15 HP motor drove the rolls and paddle wheel for transferring discharged beets.

Along with the mechanical harvest had come a reduction of quality standards of delivered beets. This reduction in standards led inevitably to a relaxing of cultural standards in the fields. The result was that thinning and hoeing operations were generally limited so as to produce crops which would submit to mechanical harvest but which would present a minimum cost of field operations.

Therefore, it became necessary to cope with the trash problem at the

beet-receiving stations and the problem, at least temporarily, became a stepchild of the processor.

A review of mechanisms designed to eliminate leafy material from root crops revealed a considerable background of development work, some of which had culminated in commercially successful topping machines for such vegetables as red beets and onions.

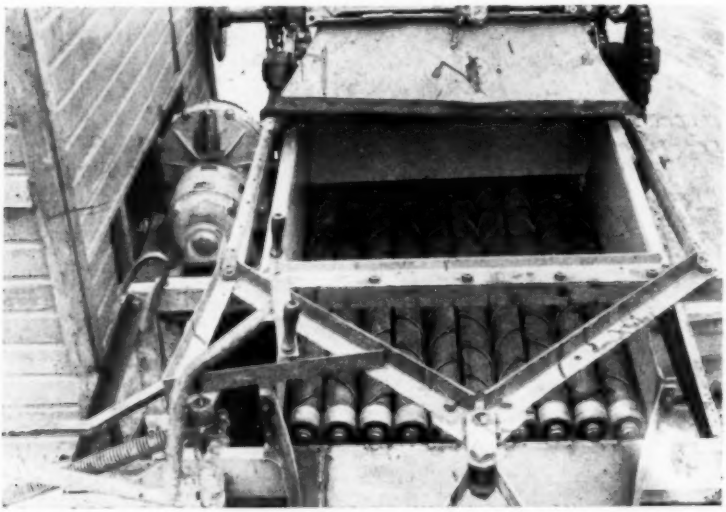

Figure 3. The second model used 4½" diameter rolls with ⅜" round flights. 3,500 tons of beets were cleaned by this screen, before the open driving gears were worn out.

S. W. McBirney[2] had done some experimental work in connection with the removal of trash from beets delivered by the Scott-Urschel harvester in the years following 1940. The oppositely rotating, helically-fluted rolls employed by McBirney were inadequate (because of space limitations) to solve the trash problem of the Scott-Urschel harvester. It showed every indication, however, that such rolls presented a means of sharply discriminating between sugar beets and the foreign matter (leaves, weeds, clods, et cetera) which formed the complex of sugar beet trash.

It was recognized that, to handle a flow of beets of such magnitude as is handled in a receiving station, a relatively large bed of helically-fluted rolls would be required. Accordingly a pilot machine was built in which all dimensions were based pretty much on guess, since in the experience of the designer no machine had ever been built to handle a flow of beets at rates on the order of two tons per minute. This pilot machine employed

[2]Senior Agricultural Engineer, Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture.

ten oppositely rotating rolls, 4 inches in outside diameter and rotating in alternately opposite directions. Rotation speeds ranging from 225 to 350 r.p.m. were tried.

Some rather astonishing results emerged from these early trials. The bed of rolls extracted very nearly 100 percent of all material other than sugar beets, including artificially introduced masses of soil, mud, rocks, weeds and

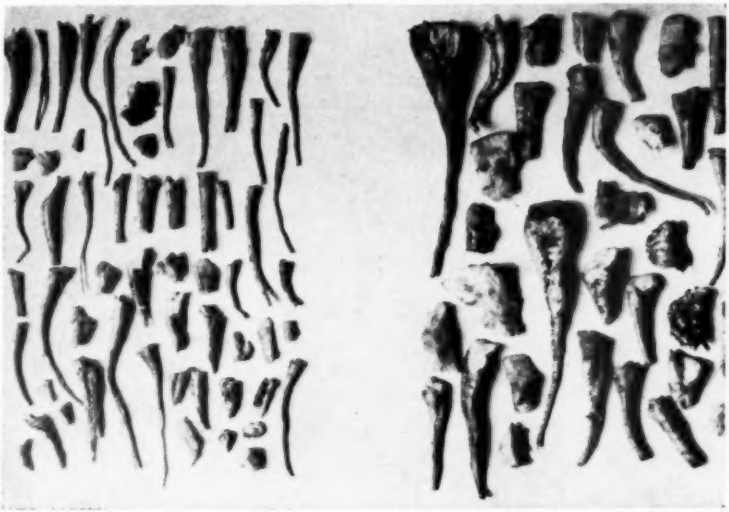

Figure 4. Left—beet fragments delivered by the fluted roll screen. Right—beet fragments delivered by a conventional Rienks screen.

The fluted roll screen delivers more fragments than does the Reinks screen, but their small size makes the total weight about one-half as great.

beet tops. Unfortunately the machine was equally effective in removing the tails from nearly all beets, and delivering to the trash discharge an alarming percentage of useful sugar beet tissue.

There appeared to be one definite point of attack on the problem of tail breakage. The rolls were so located as to present a space ¾ of an inch wide between each pair of rolls. The helical flights on the rolls consisted of a ½ inch square iron rod forming a double lead with a pitch of 18 inches. Therefore, a closer spacing of rolls suggested itself. A second model was constructed in which 4½-inch diameter rolls were employed, spaced ½ inch apart. The flights consisted of ⅜-inch round iron rod, again arranged as a double helix with 18-inch pitch. This roll bed was mounted on a Silver-Roberts piler, replacing the usual Rienks screen.

In this application the screen was subjected to all of the abuse incidental to the piling of beets received from unselected truck loads. Thirty-five hundred tons of beets passed over the screen during its installation

in this piler. This accomplishment was not without some rather heroic maintenance measures. The open gears which transmitted motion from roll to roll were virtually destroyed by abrasion, even though direct entrance of abrasive matter was eliminated by shielding. Driving the rolls by means of a serpentine roller chain was tried, but this arrangement proved even less durable than the original gear drive. It became evident that a totally enclosed, oil-immersed gear drive, following the practice of automotive transmission construction, would have to be employed if durability were to be achieved.

Figure 5. A fourteen-roll screen was preceded by a short Reinks screen at the Woodland truck dump.

The breakage of beet tails by this second screen was reduced to a point where it could be considered a secondary problem. There was, of course, some breakage of the beets. But tests indicated that this breakage amounted to about one-half the weight of the beet fragments found in the discharge of the conventional Rienks screen. The roll screen broke off a larger number of beet tails than the Rienks screen, but at such a small diameter that their total weight averaged about ½ percent of the total beet weight. The Rienks screen under similar conditions removed beet fragments and small beets weighing approximately 1 percent of the total beet weight.

The necessarily short rolls required for installation in the piler left something to be desired. It appeared that instead of 4 feet of length available in the piler, 6 feet would have provided almost complete trash removal. Even so, the beet piles made with this screen were strikingly free of visible trash, and did not create the heating troubles witnessed in the adjacent pile which had been deposited by a piler with the conventional Rienks screen.

During the latter part of the piling experience a problem with grave implications presented itself. As the rainy season approached, muddy beet loads became increasingly frequent. Certain types of sticky clay when present in the load would so envelop the rolls as to bind them completely and stall the 20-H.P. driving motor. There was a striking contrast between moist dirt and dry dirt in relation to the machine's performance. The capacity for

Figure 6. The roll screen installed at the Isleton dump handled close to 19,000 tons without major repairs.

dry soil was apparently unlimited as as much as 4,500 pounds of soil in a five-ton beet load had been extracted with no difficulty.

In an effort to improve the machine's ability to handle sticky mud, a new set of gears was installed so as to produce a difference in speed of rotation of adjacent rolls. At the same time the flights were removed from alternate rolls, since the difference in roll speed would preclude the possibility of proper timing and the meshing of flights.

After making this revision the machine was again installed in the piler and operation resumed. There was a marked improvement in the screen's ability to cope with the mud situation, but under extremely muddy conditions the screen became inoperable.

The third installation of a roll type screen was made on the Woodland factory truck dump. This dump is a very high capacity unit, the main belt delivering an average of 7 tons per minute, with peaks reaching 12 tons per minute. Two Rienks screens, each 7 feet wide, were usd originally for cleaning beets at this dump.

A roll screen containing 14 rolls, each 6 feet long, was installed in place of one of the Reinks Screens. This screen embodied all mechanical

details which were considered necessary in the light of the rapid wear previously experienced. All gear and roller chain drives were enclosed in an oil bath and particular pains were taken in regard to bearing seals.

This installation proved to be a step backward in the progress of developing the roll screen. Limitations in space made it necessary to mount the screen in a horizontal position and this was fatal so far as properly handling the volume of beets presented by this high capacity dump. True, the removal of trash and dirt compared favorably with the adjacent Rienks screen, but it was painfully evident that discharge of beets by the roll screen was so slow as to cause the beets to pile up into a thick layer. (The prime requisite of any successful screen is that the beets shall be spread in a layer whose thickness is no greater than that of a single beet.)

After the screen had been used in this location for thirty days, unseasonal rainfall produced a severe mud condition and the time lost in cleaning the roll screen became so great that it became necessary to replace it with the original Rienks screen.

The fourth installation was made with caution as to location. A receiving station (Isleton, Calif.) was selected which handled only beets from peat soils and which was very unlikely to present a mud problem. The screen was mounted on a 10-degree slope even though this necessitated shortening the rolls to a length of 4 feet. Except for shortening the rolls, no changes were made in the screen as previously installed in the Woodland factory dump.

In general it may be stated that the season's experience at the Isleton dump was completely successful. The performance of the screen here tabulated:

	Percent Clean Beets			% Tare
Screen Type	**Maximum**	**Minimum**	**Average**	**Average**
Armer Fluted Roll	98.41	94.87	96.87	3.13
Eccentric Ring, 1948	97.06	86.87	93.52	6.48
Average, Dist. 2, 1949 (Exclusive of Isleton)	95.76	81.26	92.92	7.08

This comparison demonstrates the relatively high effectiveness of the roll screen. This effectiveness is emphasized by the fact that while Isleton has, historically, been an exceptionally trashy dump, carloads from this dump during 1949 were almost free of any visible trash.

Between August 1 and November 17 and 18, 826.5 gross tons of beets passed over the Armer screen. During this time wear on the roll tail bearings made their replacement necessary. These bearings are the weak spot in the design, since mud is forced into them despite the use of triple seals.

Conclusions

1. **The fluted roll type of screen is highly effective in the removal of all foreign material customarily associated with sugar beets.**
2. **This screen is incapable of operating in the presence of appreciable quantities of certain sticky clay soils.**
3. **The screen can be made mechanically durable by employing high class automotive type construction.**
4. **Horsepower requirements are high, since installed horsepower must be adequate to maintain rotation when large objects or bunches of trash are caught between adjacent rolls.**

Attachments to Scott-Urschel Sugar Beet Combine to Improve Dirt and Trash Removal

LEE J. TALLADAY[1] AND PERC A. REEVE[2]

The objective of all sugar beet harvesters is to deliver beets to the receiving station which are properly topped and are free from dirt, trash and foreign matter. The elimination of excessive dirt is especially to be desired in the eastern sugar beet growing area. More than 90 percent of the beets are delivered direct from the field to the factory, the average truck haul being approximately 15 miles. However, in many instances the haul exceeds 30 miles.

This paper will describe and discuss the results secured with several units operated in conjunction with the Scott-Urschel sugar beet combine in an attempt to keep the dirt and trash at a minimum.

Figures 1 and 2 show the potato chain assembly built by Talladay & Sons, Milan, Michigan. This unit gave encouraging results as indicated by the following data: Check harvester (regular stub bar), 995 pounds haul back dirt. Regular stub bar equipped with potato chain assembly, 275 pounds haul back dirt. On 25 tons of beets harvested with the potato chain assembly there was a haul back of 3,200 pounds of dirt, or about 125 pounds per ton of beets, compared to an estimated haul back of more than 10,000 pounds of dirt on 25 tons of beets from the standard Scott Urschel harvester.

The potato chain assembly was constructed as follows: The lower 5 feet of the regular Scott-Urschel elevator were used. To the top of this were bolted 5 feet of potato chain from a Marbeet Jr. elevator. This chain was in the same plane as the rods in the original elevator and traveled at the same speed. Directly above this potato chain was another frame work with the same type of chain floating from a steel framework. This chain traveled in the same direction but at twice the speed of the lower elevator. This difference in speed caused a rubbing action on the beets which contributed materially to the effectiveness of the unit in eliminating dirt and trash. Additional units are being built by the agricultural engineering department of Michigan State College for further testing this fall.

Figure 3 shows a series of "squirrel cages" installed in the bottom of the beet elevator. This unit was built by the Scott Viner company near the end of the 1949 harvesting campaign. It shows considerable promise. Construction details can be secured by writing to Scott Viner Company, 540 West Poplar Avenue, Columbus, Ohio.

Figure 4 shows how Harold Gremel, a farmer near Sebewaing, Michigan, mounted the Reinks screens from an International sugar beet combine on his Scott-Urschel harvester. Gremel secured very satisfactory results with

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[2] Farmers & Manufacturers Beet Sugar Association.

Figure 1. Front view of the potato chain assembly built by Talladay & Sons, Milan, Mich. This unit gave encouraging results. Additional units are being built by Michigan State College for further testing this fall.

Figure 2. The potato chain assembly built by Talladay & Sons in operation in the field.

Figure 3. A series of "squirrel cages" installed in the bottom of the beet elevator. This unit, built by Scott Viner, shows considerable promise.

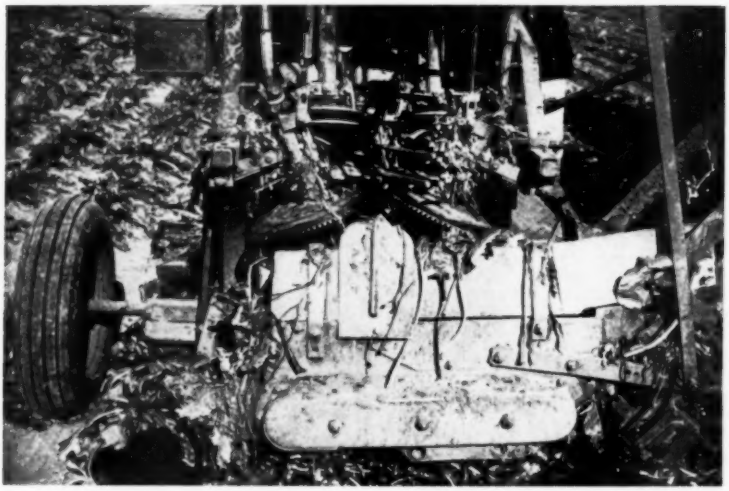

Figure 4. Harold Gremel, a farmer near Sebewaing, Michigan, mounted the Reinks screens from an International sugar beet combine on his Scott-Urschel harvester in this manner.

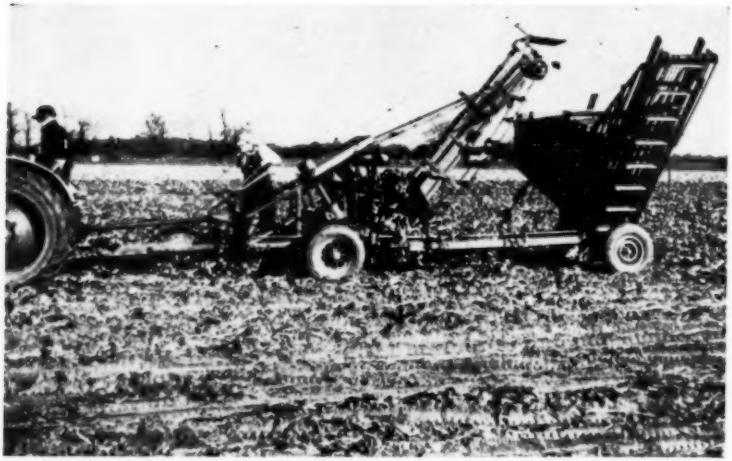

Figure 5. A self-unloading cart being operated in conjunction with the Scott-Urschel harvester.

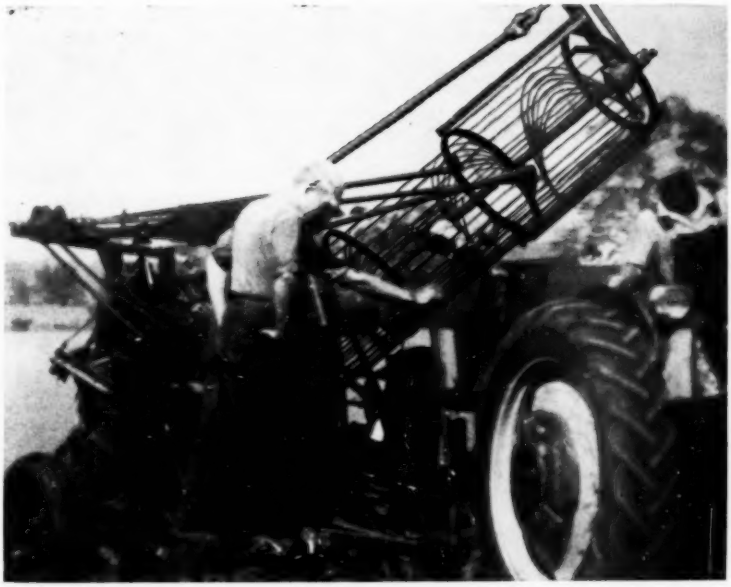

Figure 6. A spiral conveyor built by Talladay & Sons. This unit did not prove satisfactory as a means of eliminating dirt and trash.

this arrangement. Several others in the eastern area have installed Reinks rolls of one type or another on their Scott-Urschels with varying degrees of success.

Figure 5 shows a self-unloading cart being operated in conjunction with the Scott-Urschel. This type of cart as well as the small size dump carts has proved effective in eliminating dirt and trash from beets being delivered to the factory. Several commercial makes are available.

Figure 6 shows a spiral conveyor built by Talladay and Sons, Milan, Michigan. The conveyor was 24" in diameter, 12' long. The screw was a normal pitch (each revolution of the scroll would move a beet 24" up the scroll or elevator). The scroll operated at 25 RPM, and was constructed of 5/16" cold rolled rod. The cage was constructed from 3/8" cold rolled rod, the center shaft was 2" tubing. This unit did not prove satisfactory as a means of eliminating dirt and trash.

Wire and fibre brushes of various types were tested in cooperation with Clarence Hansen of the engineering department, Michigan State College, as a possible means of eliminating dirt and trash when attached to the Scott-Urschel harvester. The following are construction details of one of the units:

The wire brush assembly consisted of 24 brushes 12" in diameter mounted on 6 shafts which gave 4 brushes to a shaft with 4" between each

brush on the shaft. The shafts with the brushes revolved at 200 RPM. Brushes were so mounted in the unit that there were 10" between each row of brushes. To fill this gap a series of curved rods was welded to a framework. The top row of brushes rested on these rods. This was the bottleneck as the brushes were not stiff enough to push the beets across the stationary surface and operation in general was not satisfactory.

Figure 7 shows a combination Reinks roll-potato chain unit built by

Figure 7. A combination Reinks roll-potato chain built by Talladay and Sons. This unit gave fairly good dirt and trash removal.

Talladay and Sons, Milan, Michigan. In this unit the regular elevator was placed in front of the wheel and the small potato chain carried the beets from the Reinks rolls to the regular elevator. This unit gave fairly good dirt and trash removal, but it was felt that it required too much additional mechanism to be practical.

Figure 8 shows another experimental brush unit.

Further field testing is still needed to determine the practical value of these units for removing dirt and trash from harvested beets prior to delivery to the factory or storage piles.

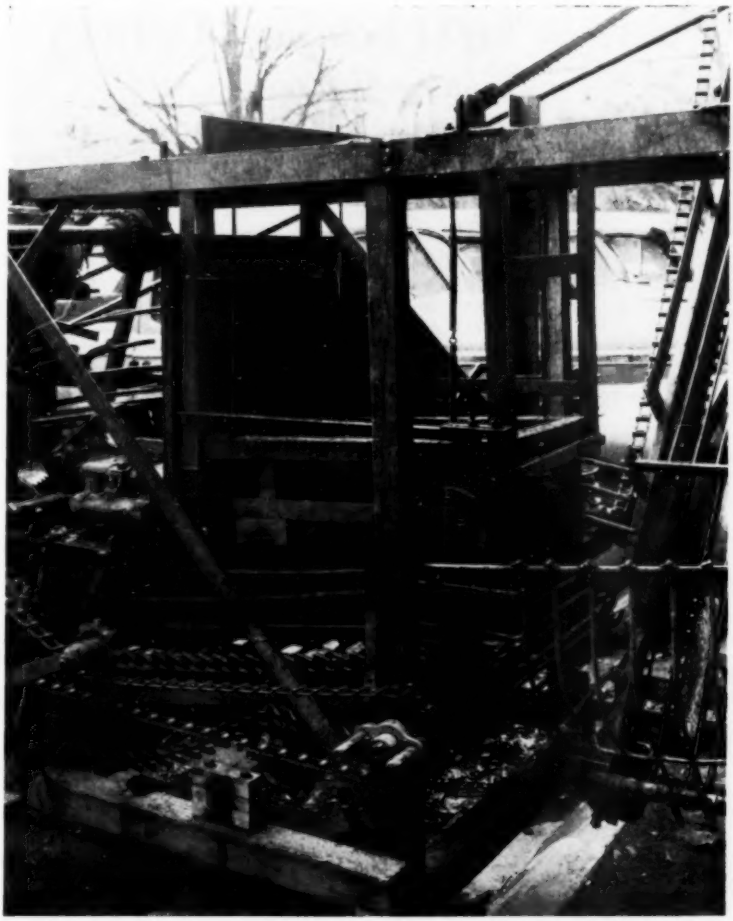

Figure 8. Another experimental brush unit. Further field testing is needed to determine the practical value of such equipment for removing dirt and trash.

Pre-Harvest Sampling for Estimating Commercial Production By a Randomized Method— Nine Years' Results for Great Western Sugar Company Territory

H. L. BUSH AND H. E. BREWBAKER[1]

Accurate pre-harvest estimates of the tonnage and sugar content of the sugar beet crop are highly important to the management of a beet-sugar company.

A scheme was devised and used in 1941 whereby pre-harvest samples selected at random were taken in an attempt to provide accurate pre-harvest estimates for both tonnage and sugar content. Results for this one year[2] indicated considerable improvement in precision over previous methods used. This scheme, with slight changes, has been used continuously since that time. The method used in 1944[3] and later years was similar in most respects to the original scheme except for a geographic stratification of each factory district into receiving-station districts.

The scheme was intended to provide a considerable degree of accuracy for each factory acreage as a unit.

Results for 1941-49

Results are presented here only for the Colorado and Nebraska districts, since records are not complete for other districts for all 9 years during which this method has been used.

The final yields in tons of beets per acre and sugar percentage for the contracts sampled compared with final district averages for Colorado and Nebraska, 1941-49, are presented in Table 1. Also included is the range of differences obtained for the same comparison at each of the factories included in each district, the number of factories being included in the table.

The average percentage of sugar for the contracts sampled agrees very closely with the district averages. However, the district averages for tons of beets per acre are slighly but consistently above the yields obtained for the contracts sampled, although both plus and minus fluctuations have resulted for individual factory averages. The largest difference of +1.09 tons (one Nebraska factory, 1946) is not so large as the error of ±1.58 tons, which was obtained at the 5% level of significance for the 1941 data.

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[1] Statistician-Agronomist and Director, respectively, Agricultural Experiment Station, The Great Western Sugar Company, Longmont, Colorado. Credit is extended to Mr. E. Ward of the statistical department for cooperation in procurement of data.

[2] Brewbaker, H. E., and Bush, H. L. Pre-harvest estimate of yield and sugar percentage based on random sampling technique. Proc. Amer. Soc. Sug. Beet Tech., 184-196, 1942.

[3] Brewbaker, H. E., and Bush, H. L. Four years' results of pre-harvest sampling in estimating yield and sugar percentage. Proc. Amer. Soc. Sug. Beet. Tech., 141-153, 1946.

TABLE 1. Final yield in tons beets per acre and percentage of sugar as averages for contracts sampled compared with final harvested averages for the Colorado and Nebraska Districts, 1941-49.

Year	No. of Contracts	Tons Beets per Acre: Contract Final	Dist. Ave.	Diff.	(c Range of Diff.	% Sugar: Contract Final	Dist. Ave.	Diff.	(c Range of Diff.
Colorado (a									
1941	1,057	14.78	14.79	+.01	—.74 to +.41	16.0	16.0	0	—.2 to +.2
1942	1,715	11.76	12.00	+.24	—.24 to +.51	15.0	15.1	+.1	—.1 to +.4
1943	1,198	12.54	12.82	+.28	—.47 to +.61	16.5	16.5	0	—.1 to +.3
1944	1,087	12.46	12.64	+.18	—.42 to +.91	17.6	17.6	0	—.2 to +.1
1945	1,416	12.01	12.16	+.15	—.63 to +.55	16.1	16.2	+.1	—.1 to +.3
1946	1,444	12.75	13.04	+.29	—.89 to +.77	14.7	14.8	+.1	—.1 to +.5
1947	1,631	15.16	15.28	+.12	—.46 to +.70	15.8	15.8	0	—.2 to +.1
1948	966	13.69	13.74	+.05	—.40 to +.65	15.0	15.0	0	—.1 to +.1
1949	1,119	16.43	16.49	+.06	—.87 to +.64	17.0	17.0	0	—.1 to +.1
Nebraska (b									
1941	180	16.26	16.28	+.02	—.13 to +.26	16.5	16.4	—.1	—.2 to +.1
1942	626	12.05	12.32	+.27	—.42 to +.49	14.3	14.4	+.1	—.1 to +.3
1943	391	12.11	12.39	+.28	—.69 to +.93	16.3	16.3	0	—.1 to +.1
1944	418	10.37	10.76	+.41	+.06 to +.76	16.7	16.9	+.2	—.2 to +.2
1945	473	10.74	10.82	+.08	—.14 to +.29	15.2	15.2	0	—.2 to +.4
1946	430	14.24	14.59	+.35	—.18 to+1.09	15.4	15.3	—.1	—.3 to +.1
1947	526	12.07	12.17	+.10	—.27 to +.32	15.8	15.8	0	—.2 to +.2
1948	381	11.84	12.01	+.17	—.06 to +.41	14.1	14.1	0	—.1 to +.1
1949	323	15.24	15.45	+.21	—.33 to +.67	16.2	16.3	+.1	—.1 to +.1

Note: All averages have been weighted in accordance with the number of contracts sampled in each factory district.
(a 12 factories
(b 3 factories, 1941
6 factories, 1942-47
5 factories, 1948-49
(c Range of maximum differences between district averages and final contract yields as obtained from individual factory averages.

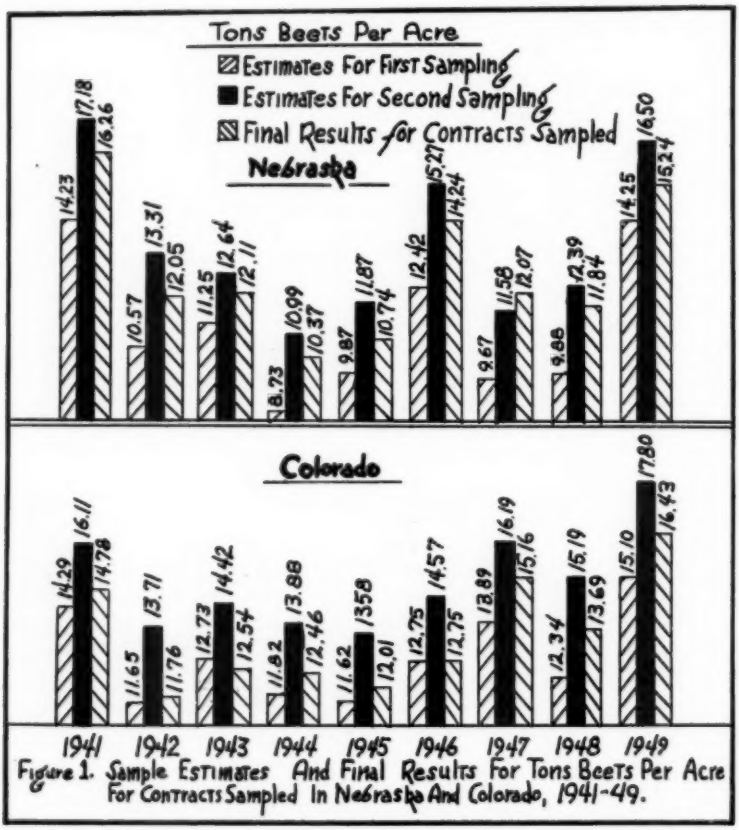

Figure 1. Sample Estimates And Final Results For Tons Beets Per Acre For Contracts Sampled In Nebraska And Colorado, 1941-49.

The arithmetical averages for both tons of beets per acre and percentage of sugar (Table 1) for the contracts sampled do not take into account the varying acreages involved in each contract. It is probable that the average tonnage obtained by weighting the yield for each contract by its appropriate acreage would tend to correct for the discrepancy between averages for contracts sampled and district averages. However, since no consideration of this point has been made in the past, data are not readily available except for one factory district (Loveland, Colorado) in 1949, which are suggestive of the possibilities for improving predictions by this method of calculations. These results are as follows:

Arithmetical Average	16.87 tons per acre
Weighted Average	17.45 tons per acre
Final Factory Average	17.51 tons per acre

Other suggestions were made[2] as possibilities for overcoming this bias. However, the information as now obtained has proved to be sufficiently accurate as a basis for making predictions to satisfy practical requirements.

The average indicated tonnage for each of the sampling dates, the first about September 1 and the second two weeks later, along with the average tonnage for the contracts sampled, are presented in Figure 1.

TABLE 2. Percentage increases or decreases for yield of roots, comparing sampling estimates with final yields of the contracts sampled.

	Colorado			Nebraska		
	Increase		Loss	Increase		Loss
Year	1st to 2nd Sampling	1st Samp. to Harvest	2nd Samp. to Harvest	1st to 2nd Sampling	1st Samp. to Harvest	2nd Samp. to Harvest
1941	12.74	3.43	8.26	20.73	14.27	5.36
1942	17.68	.86	14.30	25.92	14.00	9.47
1943	13.28	—1.49	13.04	12.36	7.64	4.19
1944	17.43	5.41	10.23	25.89	18.79	5.64
1945	16.87	3.36	11.56	20.26	8.81	9.52
1946	14.27	0	12.49	22.95	14.65	6.75
1947	16.56	9.14	6.36	19.75	24.82	+4.23
1948	23.10	10.94	9.87	25.40	19.84	4.44
1949	17.88	10.88	7.70	15.79	6.95	7.64
Mean	16.65	4.73	10.42	21.01	14.42	5.42

As indicated in Figure 1 and presented as percentage increments in Table 2, there has been considerably more growth of beets after September 1 in Nebraska than in Colorado, the increases expressed in nine-year averages from first to second sampling dates being 16.65 and 21.01 percent for Colorado and Nebraska, respectively, with increases of 4.73 and 14.42 percent from first sampling to final harvest for the same respective comparison.

There are indicated losses of 10.42 percent and 5.42 percent (Table 2) for Colorado and Nebraska, respectively, comparing the harvested final yield with that indicated at the time of second sampling. This drop is quite consistent, with the exception of 1947 in Nebraska, when there was an indicated gain of 4.23 percent in yield of beets for the same comparison. Also, as previously indicated,[3] this does not represent the entire loss, since there is continued development on some, if not all, fields after the second sampling. The source of these losses was discussed in that paper.

These percentage figures may be used, either individually or in combination, to predict yields for any year. The accuracy of the predictions will, of course, increase as yearly results are accumulated and must be accompanied by a careful consideration of the local conditions affecting the growth of the crop.

The percentage of sugar has also shown a consistently more rapid increase in Nebraska than in Colorado after September 1 as indicated in Figure 2, the results being presented in terms of percentage increase increments in Table 3.

TABLE 3. Percentage of sugar expressed in terms of percentage increase between sampling dates and final results for contracts sampled.

Year	Colorado Increase 1st to 2nd Sampling	Colorado 1st Samp. to Harvest	Colorado 2nd Samp. to Harvest	Nebraska Increase 1st to 2nd Sampling	Nebraska 1st Samp. to Harvest	Nebraska 2nd Samp. to Harvest
1941	3.73	19.40	11.51	7.35	21.32	13.01
1942	7.14	19.05	11.11	8.40	20.17	10.85
1943	13.28	28.91	13.79	21.37	39.32	14.79
1944	15.75	38.58	19.73	23.42	50.45	21.90
1945	15.20	28.80	11.81	18.58	34.51	13.43
1946	11.50	30.09	16.67	14.66	32.76	15.79
1947	5.43	22.48	16.18	11.21	36.21	22.48
1948	10.66	22.95	11.11	15.09	33.02	15.57
1949	12.03	27.82	14.09	13.60	30.40	14.79
Mean	10.52	26.45	14.00	14.85	33.13	15.85

The increases, based on a nine-year average, from first to second sampling are 10.52 and 14.85 percent for Colorado and Nebraska, respectively, while the increases from first sampling to harvest are 26.45 and 33.13 percent for the same respective comparisons. The increases from second sampling to harvest are more nearly alike in the two states, being respectively 14.00 and 15.85 percent. These average increase values may be used in predicting sugar percentage in a manner similar to that used in predicting beet tonnage.

As an indication of the expected accuracy of future predictions, theoretical estimates based on the sampling results for the past 9 years, and using

TABLE 4. Harvested average tons beets per acre compared with managers' estimates and yields estimated by pre-harvest samples.

Year	Managers' Estimate Aug. 31	Estimated (a Yield 1st Sample	Estimated (a Yield from 1st Samp.	Estimated (b Yield 2nd Sample	Estimated (b Yield from 2nd Samp.	Harvested District Average	Differences Harv. minus Mgrs'. Est.	Differences Harv. minus Est. 1st Samp.	Differences Harv. minus Est. 2nd Samp.
Colorado									
1941	14.81	14.29	14.97	16.11	14.43	14.79	—.02	—.18	+.36
1942	13.85	11.65	12.20	13.71	12.28	12.00	—1.85	—.20	—.28
1943	13.92	12.73	13.33	14.42	12.92	12.82	—1.10	—.51	—.10
1944	12.57	11.82	12.38	13.88	12.43	12.64	+.07	+.26	+.21
1945	13.31	11.62	12.17	13.58	12.16	12.16	—1.15	—.01	0
1946	12.57	12.75	13.35	14.57	13.05	13.04	+.47	—.31	—.01
1947	13.72	13.89	14.55	16.19	14.50	15.28	+1.56	+.73	+.78
1948	13.14	12.34	12.92	15.19	13.61	13.74	+.60	+.82	+.13
1949	14.68	15.10	15.81	17.80	15.95	16.49	+1.81	+.68	+.54
Nebraska									
1941	15.19	14.23	16.28	17.18	16.25	16.28	+1.09	0	+.03
1942	14.16	10.57	12.09	13.31	12.59	12.32	—1.84	+.23	—.27
1943	14.60	11.25	12.87	12.64	11.95	12.39	—2.21	—.48	+.44
1944	12.10	8.73	9.99	10.99	10.39	10.76	—1.34	+.77	+.37
1945	12.40	9.87	11.29	11.87	11.23	10.82	—1.58	—.47	—.41
1946	12.37	12.42	14.21	15.27	14.44	14.59	+2.22	+.38	+.15
1947	11.80	9.67	11.06	11.58	10.95	12.17	+.37	+1.11	+1.22
1948	13.28	9.88	11.30	12.39	11.72	12.01	+1.27	+.71	+.29
1949	14.26	14.25	16.30	16.50	15.61	15.45	+1.19	—.85	—.16

Note: All averages were weighted on the basis of the number of contracts sampled in each factory district.

(a Tonnage indicated by first sampling increased by 4.73 and 14.42 percent for Colorado and Nebraska, respectively.

(b Tonnage indicated by second sampling decreased by 10.42 and 5.42 percent for Colorado and Nebraska, respectively.

the mean nine-year increase in tonnage of 4.73 percent from first sampling to harvest and the decrease of 10.42 per cent (Table 2) from the second sampling to harvest for Colorado, and 14.42 and 5.42 percent for the same respective comparisons in Nebraska, are presented in Table 4 along with factory managers' estimates based on the general appearance of the beet crop as made on August 31, a few days before the first pre-harvest samples were taken.

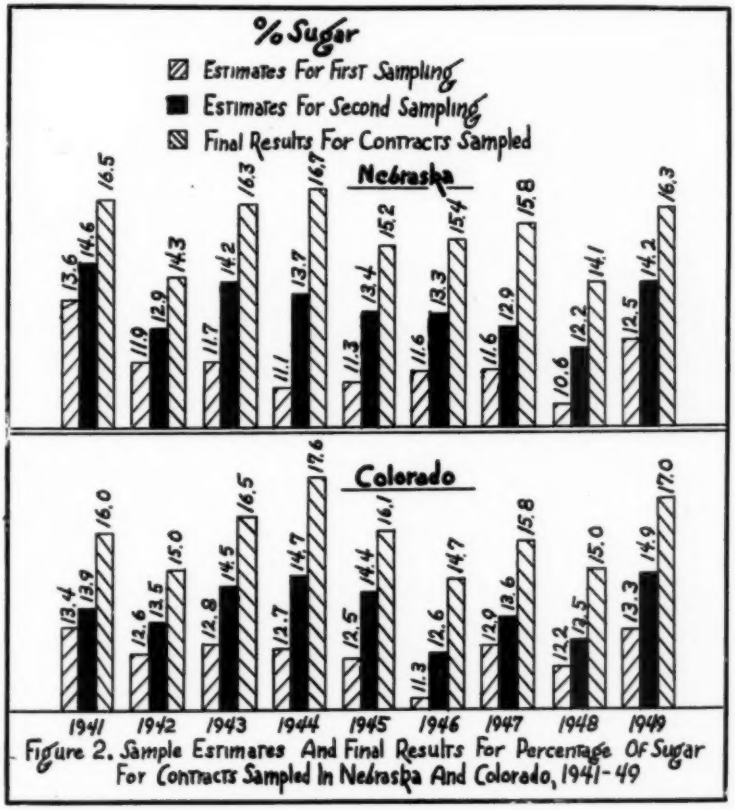

Figure 2. Sample Estimates And Final Results For Percentage Of Sugar For Contracts Sampled In Nebraska And Colorado, 1941-49

In general, the estimates, based on either the first or second sampling, resulted in estimated tonnages which more nearly approached actual yields than did the managers' estimates. The differences between estimated yields, calculated from pre-harvest samples, and tonnage actually harvested range from —.51 to +.82 tons per acre for the first sampling date and from —.28 to +.78 tons per acre for the second sampling date, and the range in differences between the managers' estimates and the final yields is —1.85 to

+1.81 tons per acre for Colorado. Similarly, differences for Nebraska are —.85 to +1.11 and —.41 to +1.22 tons per acre for the two respective samplings and —2.21 to +2.22 tons per acre for managers' estimates.

It is likewise possible to predict final sugar content in this same manner with greater accuracy than was possible by previous methods.

Summary and Conclusions

1. A scheme for random sampling the sugar beet acreage to aid in making predictions as to the expected yield and sugar content is discussed, using data resulting from 9 years' experience in the Colorado and Nebraska districts of The Great Western Sugar Company.

2. The fields sampled were found to yield, as an average for all factories within a district, slightly below the district average in tons of beets per acre, but the sugar content was essentially the same for both contracts sampled and district averages. Results are presented which indicate that a weighted average for the yields of the contracts sampled, based on the acreage in each contract, might have resultd in a closer agreement with district averages than do the results for tons of beets per acre based on arithmetical averages of all contracts sampled without regard for size of field.

3. There is considerably more increase in both size of beets and sugar content after the first sampling (September 1) in Nebraska than in Colorado. A loss in tonnage harvested from tonnage indicated at the second sampling is shown for both the Colorado and Nebraska districts, this loss being lower in Nebraska than in Colorado.

4. Theoretical estimates of the yield in tons per acre based on the nine-year results are presented in comparison with factory manager's estimates for each year. The estimated yields from pre-harvest samples agree more closely with actual tonnages, as harvested, than do the managers' estimates.

The Distribution of Air in Sugar Beet Stock Pile Ventilation Systems

C. M. HANSEN[1]

Sugar beet stock pile ventilation has brought a change to the harvest campaign in the eastern area. With the simple process of blowing cool night air into a pile of beets, the processor can receive beets on a larger scale through expanded facilities at an earlier date than was heretofore deemed wise. The insurance given by this system affords the processor an opportunity to speed up deliveries and thus cut the harvest period to a minimum, avoiding much of the usual inclement November weather.

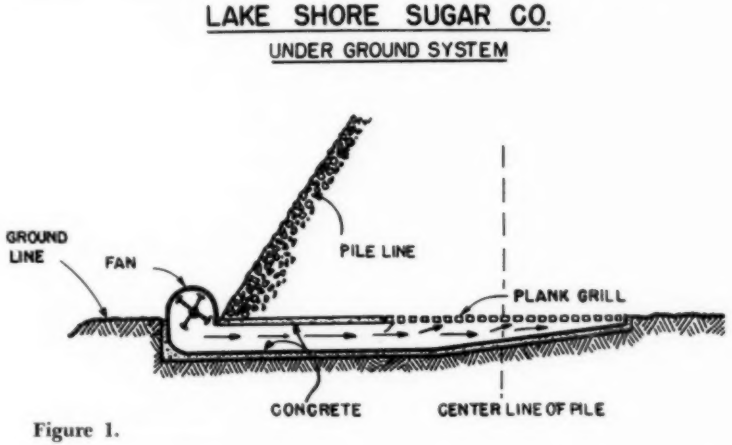

Figure 1.

Elimination of restricted delivery will give the farmer an opportunity to harvest his crop to the limit of his equipment. This means that the processor can be assured of fresh beets. With the advent of the mechanical harvester, which ironically made the delivery problem more acute, beets can be taken from the ground direct to the ventilated pile. This would cut the beet shrink loss to a minimum, assuring the farmer of maximum tonnage. However, the most important saving is the saving in sugar. From data taken by Fort and Stout (1)[2] we can see that with increasing beet temperature the sugar loss due to respiration alone is tremendous. On this factor alone, a properly installed stock pile ventilation system is a paying proposition.

Much basic information has been obtained on the storage of the sugar beet. The application of these data required a well organized research program. It was necessary to determine the most feasible method of ventilating the stock piles. It was also necessary to develop a technique to evaluate the

[1] Assistant Professor, Section of Agricultural Engineering, Michigan State College, East Lansing, Michigan.

[2] The numbers in parentheses refer to literature cited.

various proposed ventilation systems. The need for this information is emphasized forcefully by the data obtained during the 1947 M.S.C. sugar beet ventilation experiment (2). These data indicate that beets which were treated at the rate of 10 cfm of night air per ton lost about 3 times as much sugar as the beets which received 20 cfm. Granted that these data are of only relative value, they do point out the fact that the air should be as evenly distributed as is economically feasible.

Our objective in stock pile ventilation should be to keep the beets as near 32° F. as possible. Even though a pile might keep from spoiling without ventilation (for every degree of temperature drop means a saving of sugar), it is poor economy to treat a portion of a pile to twice as much air as another.

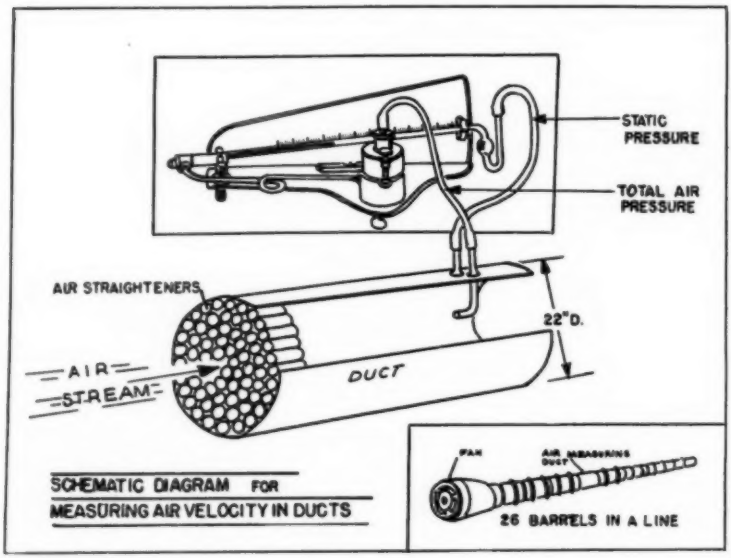

Figure 2.

By the same token no system should be powered beyond requirements. This fact is further emphasized by data obtained on two commercial stock piles this past fall. One pile had cross ducts placed on 20-ft. centers and the other on 30-ft. centers. By captive sample analysis the pile which had ducts on 20-ft. centers showed 28% greater savings of sugar. Yet in spite of the limited experience with stock pile ventilation the processors of this area believe in it, for nearly 26% of Michigan's beets were piled over air ducts in 1949.

Systems Used

The two basic types of stock pile ventilation systems which were used in Michigan during the 1949 campaign are the surface and the underground. The surface systems were installed as the beets were piled. The ducts were

spaced at regular intervals 20 feet apart the length of the pile and a place was provided for a fan on each duct. It is not necessary to provide a fan for every duct in this type of installation, for as soon as the beet temperature is down the fans can be placed on every other duct, or 40 feet apart. The fan or duct openings must be closed except during the blowing operation. Both steel barrels and steel road culvert tubes were used as ducts, and in one installation the ducts were steel fabricated sections. The performance of these ducts will be discussed further in this paper.

Two types of underground systems were also used. Michigan Sugar Co. forced air into the flumes at two of its plants. The flumes were 340 to 365 feet long. Two fans having a capacity of 16,000 cfm were installed at both

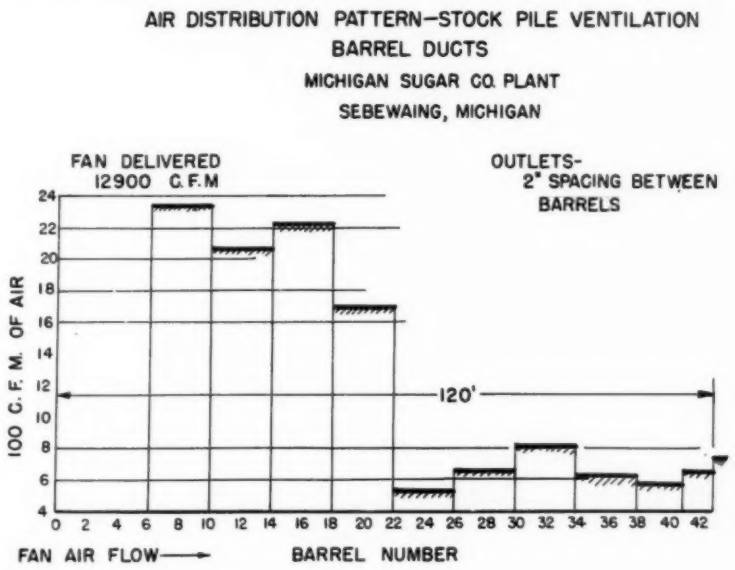

Figure 3.

ends of each flume, blowing the air toward the center of the flume. The fans should be placed on the ground or floor of the flume for two very definite reasons. First—if the fans are several feet above the flume it will cause an unnecessary bend in the header duct and restrict air flow. Second—during the still clear fall nights there is apt to be a differential of from 5 to 10 degrees in ambient temperature within a height six feet from the ground.

The management of Lake Shore Sugar Co. envisioned what stock pile ventilation could do for it and built 18 underground cross ducts on 30-ft. centers. Their managers turned to the men in their shops for the necessary steel fabrication. Ten-HP electric motors were used to power the fans, which were also made in their shops. The concrete underground duct side

walls became a part of the lower fan housing and the air was forced directly through the 4x6 plank grill work and into the beet pile. (Figure 1).

Technique Used to Check Distribution

The basic tool used to check the distribution of air was a three-inch Ellison draft gage. This instrument registers inches of water at .001 graduations, and with it we can obtain the static pressure, which is the force exerted against the sidewalls of the duct, and the velocity-pressure from which can be obtained the velocity of air in feet per minute through mathematical formulation. A technique was developed in which pitot and static pressure tubes were installed 2½ diameters down stream from the air straighteners (3). The air straighteners assured us of the necessary smooth laminar flow. This appartus was built into a smooth steel pipe having a diameter equal to the steel barrels. After making a reading it was moved down the duct at given intervals for subsequent readings (Figure 2). This technique had to be varied somewhat for the underground systems.

Results

Using the method described in the foregoing discussion we were able to obtain data which might be expressed in graph form for clarity. Three graphs of the data taken on various systems were selected at random. For this reason they are not necessarily indicative of the efficiency of that system. Our first research began on the steel barrel duct system (Figure 3). Imagine, if you will, that you are looking at a cross section of a beet pile with a line drawn directly over the air duct. The steel barrels in this particular case were spaced with approximately two inches between them. A fan delivering 12,900 cfm is at the left. The information which we have on this graph shows that there is a definite need for spacing the first barrels closer. Static pressure was much greater the first 22 barrels—consequently there was a greater dispersal of air. Total length of this particular duct is 120 feet. This is about the maximum length at which barrel ducts will operate effectivly with this particular type axial flow fan.

Some experimental work was done with road culverts as ducts. Data were obtained on two sizes, 18" and 24" diameters (Figure 4). Using the data obtained from the barrel ducts 1½" holes were drilled, allowing for about 27 square inches of opening per foot of duct. This area was increased to 34 for the tubes between 48 and 72 feet, which tended to level off the curve. The sudden rise at the end of the duct is typical of much of the data which were obtained. Further study is needed on this type of duct to determine the best possible arrangement of holes.

The flume did not provide the most satisfactory air duct; nevertheless, the operation was successful (Figure 5). The fans in this case were rated at 16,000 cfm at 3" static, yet due to the necessary restriction which the installation imposed on them they delivered something more than 10,000 at about 1.7 static. The left side of this graph is rather orderly with a sharp rise in the center area. The release of this large volume of air was corrected once the distribution pattern was known. All that was needed in this case was to space the duct covers closer and force the air into the area between the east 100 to 150 mark.

A somewhat different technique was used to check the Lake Shore Sugar Company's underground ducts. The shop-made fans were quite efficient and

delivered approximately 17,000 cfm at .92 inches static. The duct as shown in the graph is 40 feet long (Figure 6). It represents only the section which distributed the air into the beets. This distribution curve ranges between

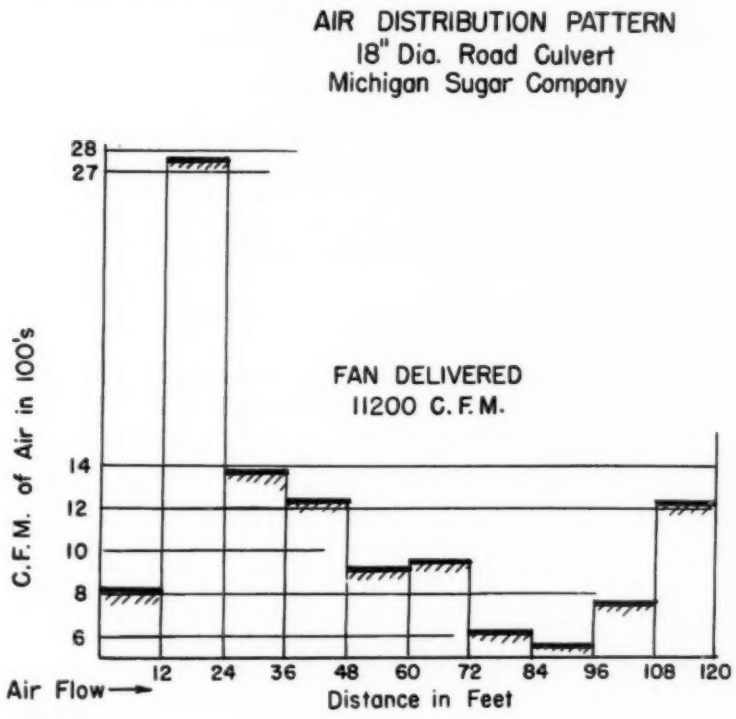

Figure 4.

700 and 1,200 cfm. This was not the most desirable pattern, and so an attempt was made to rectify it. Three 6x6 wood blocks were placed at given intervals in the ducts. The blocks did increase the volume release of air throughout the first ten feet, but they caused excessive turbulence and did not improve the pattern.

Rates of Air Per Ton of Beets

The various systems which have been discussed have different air capacities and as a result the cfm of air per ton of beets differs. The rates are as follows:

1. Portable system using axial flow fans with road culvert, or barrel ducts 16 cfm of air per ton of beets when beets are first piled, and 2 cfm to hold pile after initial cooling is accomplished.
2. Portable system using forward curved rotor fan or fabricated steel ducts, 9.3 cfm per ton.

3. Underground system, flume 15.6 cfm per ton.
4. Underground system, Lake Shore Sugar Co., 24.3 cfm per ton.

Smoke Check

It was felt that a visual check of the various distribution patterns would be interesting. For this reason smoke was injected into the air stream of the fan and forced through the pile. A word of caution as to the use of smoke for this purpose. It is necessary to use a compound which will not be toxic to either the beets or steel ducts. For example, we considered sky-writing smoke, but it leaves a heavy acid vapor. This method of checking gives one a very good idea of what is happening in the beet pile.

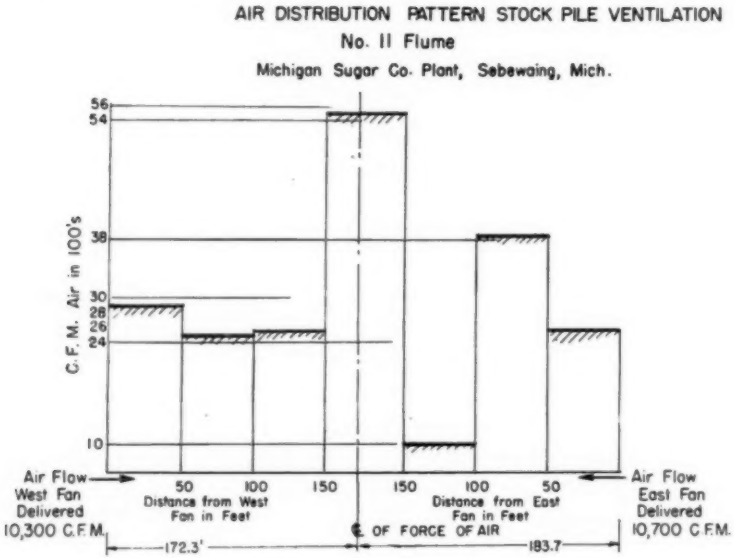

Figure 5.

Air Losses

As is true of much research one obtains other valuable information. Due to the fact that we must observe safety precautions, ¼" wire mesh screen was placed over the intake side of the axial flow fan. A secondary purpose of this screen is to keep leaves and trash from being blown into the pile. A check was made to determine whether or not this screen restricted the fan operation appreciably. It was found that it cut the fan's output 24%, whereupon another screen made of chicken wire was substituted which met the requirements.

Barrel ducts which have been in service a year or more often sustain dents when they are reclaimed. Dents of any consequence restrict air flow markedly. A seven-inch dent, for instance, will retard flow 21%.

Temperatures

Temperatures of the ventilated beet piles were taken at various locations at about the 10-ft. level. Standard mercury thermometers were suspended

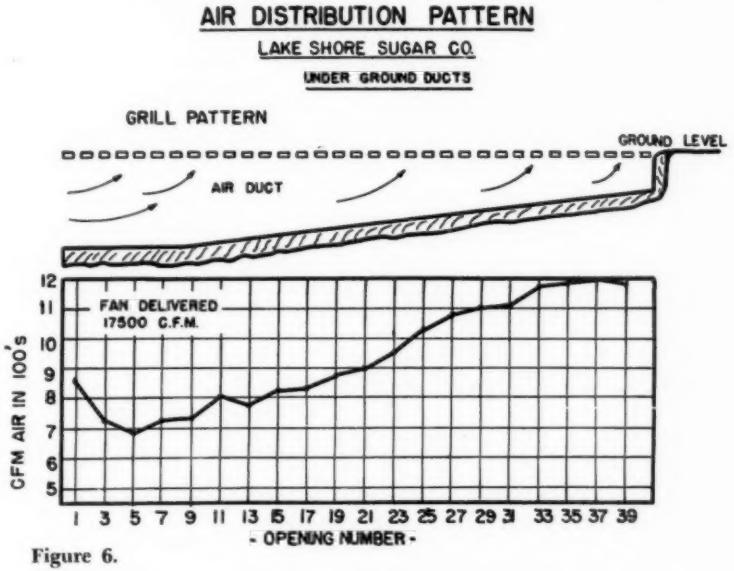

Figure 6.

on strings down 5/8" pipe to be read at regular intervals. It would be superfluous to present all of the temperature data in graph form, so a comment or two on the subject will suffice. In general the fans were turned on only when the beets affected by that particular fan were 5° F. warmer than the ambient air. However, it was found beneficial in some cases if the fans were operated with only a degree differential. For this reason fan hours will vary from year to year. This past fall, for instance, on one 58,200 ton installation beets at one point were not ventilated more than 272 hours.

If we compare two rates of application of air on two different piles which were ventilated at the same time we notice that the beets which were treated with a lower rate of air, 9.3 cfm as against 24.3 cfm, were from 1 to 5 degrees warmer. These temperatures varied as the ambient air.

Costs

It is rather difficult to determine the cost of a stock pile ventilation system for one cannot set up a unit value. There are cases in which overhead is fixed such as in the cost of supervision. One man, for instance, can tend the fans, take readings, etc., on 50 to 70 thousand tons of beets with little more effort than is needed for 10 thousand. Also, many plants have fixed outside power rates which are imposed due to the nature of the seasonal operation. However, there are certain costs which can be con-

sidered (Table 1). There is some question as to whether or not the steel road culvert would not last longer than 10 years, in which case this system would be the least expensive.

The cost of placing portable ducts as the pils is formed and removing them when the beets are recovered was not computed with costs.

The supervision cost might be cut from $.012 per ton by the addition of automatic thermoswitches but there is no question that competent labor is much more satisfactory. Often it is possible to take advantage of evaporative cooling, lowering the temperature of beets by blowing in air which is the same temperature as the hottest spot in the pile.

Table 1.—Costs.

Type of System	Initial Cost /Ton	Total Equipment Cost/Ton for Given Period as Indicated	Power Cost /Ton at .03/k.w.hr.	Supervision /50,000 Tons	Duct Cost /Foot, 10-Yr. Period	Total Cost /Ton
Barrel Duct	.037	10 Years—.0058	.037	.012	2.00[1]	.0548
Road Culvert Duct	.058	10 Years—.0058	.037	.012	2.00[2]	.0548
Prefabricated Steel Duct	1.057	20 Years—.05	.05	.012	2.10	.112
Factory Flume	.10	20 Years—.005	.162	.012		.179
Lake Shore Co. Underground	1.078	20 Years—.054	.102	.012	9.80	.168

[1] Steel barrels replaced every three years.
[2] Road culvert replaced every ten years.

Conclusions and Summary

There are a few conclusions which might be drawn from the research work which was done during the 1949 harvest campaign.

1. **Indications are that the least expensive surface portable air ducts can be fabricated from standard 16 to 18 gauge 18″ diameter road culvert.**
2. **Stock pile ventilation can be accomplished at an annual cost of between 10 and 16 cents per ton of beets.**
3. **Stock pile ventilation is a paying proposition, for if the beet temperature is lowered 3 degrees, from 68° to 65° F., for 6 or 7 days, a processor can pay for the season's ventilation costs on the respiration factor alone.**
4. **Further research is needed to determine the best possible arrangements and sizes of openings in the road culvert ducts.**
5. **Static pressure in ducts should be held at a minimum.**

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Commercial Ventilation of Beets In Storage

L. P. ORLEANS AND ROBERT H. COTTON[1]

A previous paper (3)[2] reviewed the early work on ventilation of sugar beets in storage. The purpose of this paper is to present the results obtained from ventilation performed at Sidney, Montana, in 1948; Carlton, California, in 1949, and Hardin, Montana, in 1949.

Experimental Method

Captive samples were used in all ventilation work to determine the savings obtained. These samples were made by matching triplets of beets from the same truckload for size and shape. The beets were cleaned by brushing off the adhering dirt, using care not to injure the beet, and from each triplet one beet was placed in a ventilated pile sample, one in a check pile sample, and one in a laboratory sample. Triplets were matched and cleaned for each set of samples until there were approximately forty pounds of beets in each sample. The laboratory sample was analyzed for purity and sugar content, and the other two samples were weighed and then placed in corresponding positions in their respective piles. The two piles were made simultaneously and side by side. Open mesh cabbage bags were used to hold the samples in the work at Sidney and Hardin, and bags made from one-inch mesh chicken netting were used for the work at Carlton. The captive samples remained in the piles until the beets were processed by the mill.

When the beets were removed for processing, the captive samples were again weighed and then analyzed in the laboratory for sugar and purity. Thus from the difference between the two samples we could calculate the actual savings obtained by ventilation. The results for each experiment were also analyzed statistically by analysis of variance to establish the significance of the differences between the ventilated and check treatments.

Sidney, Montana, Ventilation—1948

A 2,600-ton pile was ventilated using three 7.5 hp. axial flow fans having a capacity of 13,500 cubic feet per minute or an air supply of 15.5 CFM per ton of beets ventilated. Ducts to carry the air into the pile were constructed using 55-gallon oil drums as suggested by M. G. Frakes (2) of Michigan Sugar company. Our procedure differed from previous work in that two thermostats were used with each fan to operate the fans between the preset temperatures of the thermostats. Auomatic louvres were used to prevent escape of cool air from the piles through the ducts when fans were not in operation.

A brief summary of the results obtained at Sidney is given in Table 1. Temperatures of the piles were similar to those obtained by Doxtator and Downie (1), and more complete results of the work at Sidney have been

[1] Holly Sugar Corporation, Colorado Springs, Colorado.
[2] Numbers in parentheses refer to literature cited.

published elsewhere (3). Fifty captive samples were used in each pile and differences in purity and total sugar were between the 5% and 1% level of significance.

Table 1.—Results at Sidney, Montana—1948

	% Weight Loss	% Total Sugar Loss	Purity Drop	Tons Sugar Bagged per Pile	Tons Molasses Produced per Pile
Ventilated Pile	7.79	9.11	3.55	235.0	189.8
Check Pile	8.90	12.59	5.67	212.7	207.8
Difference	1.11	3.48	2.12	22.3	18.0

Economic analyses of the above data were so favorable that a commercial installation was installed in 1949 at Hardin, Montana.

Carlton, California, Ventilation—1949

Because of the extremely high temperatures encountered in the Imperial valley of California during the harvest period, the elapsed time between harvest of beets and the processing of them is held to a minimum. Although beets delivered directly to the Carlton plant are held in the storage bins only 12 to 48 hours, there is an important loss in sugar. Therefore, experiments were conducted using one 7.5 hp axial flow fan to ventilate 350 tons of beets in the storage bin. This was an air supply of 38.5 CFM per ton of beets. A duct was constructed of galvanized iron to carry the air through a spray chamber and into the bin through openings cut in the floor. A drop in air temperature of from 11 to 34° F. was obtained in the spray chamber during our tests when outside air temperatures ranged from 82° F. at night to 110° F. during the day. Two tests were used to evaluate our work with 19 sets of captive samples in one test and 20 sets in the other. Because of differences in length of time the beets were in the ventilated and check bins no statistical analysis was possible, but we were able to plot our results versus time in storage and the data shown in Table 2 are taken from these curves.

Table 2.—Results at Carlton—1949

			% Weight Retention		% Total Sugar Retention		% Purity Retention[1]		% Recoverable Sugar Retention	
Hours in Bins	Average Temp. Vent.	Average Temp. Check	Vent.	Check	Vent.	Check	Vent.	Check	Vent.	Check
0	85.0	83.7	100	100	100	100	100	100	100	100
12	74.0	85.6	98.0	96.4	99.7	99.4	99.8	99.4	96.5	94.9
24	73.0	85.2	97.1	95.5	98.6	96.9	99.1	97.8	92.1	89.0
36	.....	.....	96.5	95.1	95.3	90.8	97.1	94.4	85.4	81.1

[1] % Purity retention = $\frac{\text{purity at given time} \times 100}{\text{initial purity}}$

Hardin, Montana, Ventilation—1949

Commercial ventilation of beets was practiced for the first time by Holly Sugar Corporation at Hardin in 1949. The method of ventilating beets at Hardin was the same as that at Sidney in 1948 with thermostats used to control the fans and automatic louvres to prevent escape of cool air from the pile through the ducts when the fans were not in operation. By using thermostats to control the fans we were able to utilize the maximum

possible time for ventilation. The thermostats were set to turn the fans as soon as the atmospheric temperature dropped low enough to cool the beets, and the fans remained on until the air again became too warm to cool the beets or so cold that it might freeze the beets. We also eliminated the necessity of having a man on duty 24 hours a day to turn the fans on and off as the weather dictated and thereby saved a great deal on labor costs.

Table 3.—Average Pile Temperature at Hardin, 1949

	Oct. 7	Oct. 14	Oct. 21	Oct. 28	Nov. 4	Nov. 11	Nov. 18	Nov. 25	Dec. 2	Dec. 9	Dec. 16
Vent. Pile	48.0	39.0	37.7	39.9	39.6	38.1	36.9	35.6	36.8	34.0	34.9
Check Pile	49.5	45.8	39.7	44.9	48.9	47.4	45.3	44.6	43.4	35.4	34.1
Difference	1.5	6.8	2.0	5.0	9.3	9.3	8.4	9.0	6.6	1.4	0.8

The automatic louvres, which remained closed while the fans were not in operation, prevented the cool air from leaking out of the pile through the ducts. This did not prevent cool air seepage through the sides of the pile, but without louvres a strong outward current of cool air passed through the ducts, which offered the path of least resistance to the flow of air. Eight fans were used to ventilate 7,500 tons of beets, with an air supply of 14.4 CFM per ton of beets. Sixty-seven captive samples were placed in each pile. The results, when analyzed statistically by analysis of variance, were significant beyond the 1% level for both total sugar retention and purity change. Weekly temperatures for the ventilated and check piles are shown in Table 3. A summary of the results of the ventilation work is shown in Table 4.

Table 4.—Results at Hardin—1949

	% Weight Loss	% Total Sugar Loss	Purity Drop	Tons Sugar Bagged	Tons Molasses Produced
Ventilated Pile	6.02	4.61	.04	983.6	243.7
Check Pile	6.05	8.29	1.61	927.1	264.5
Difference	.03	3.68	1.57	56.5	20.8

After the cost of ventilation (5% repair and maintenance, power and labor) was subtracted from the gross saving, a gross profit from ventilation of $.808 per ton of beets ventilated was realized. It appears that such an installation will pay for itself in terms of net profit in three to four years of operation.

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1949 Results of Ventilated Storage of Sugar Beets

ANDREW R. DOWNIE, L. J. HOLMES, H. E. KNAPP,[1]
A. G. QUAMME, AND O. A. HOLKESVIG

Experiments to determine the effect of blowing cold night air into beet storage piles have been carried on at Rocky Ford, Colorado, and Clarksburg, California, for four consecutive years. The results for 1946 and 1947 have already been reported (1) (2)[2]. Additional experiences with this type of ventilation are herewith reported.

Experimental Procedure

The fans used in the 1948 and 1949 experiments at Rocky Ford were Navy type A-10 exhaust fans with a capacity of 10,000 cubic feet per minute. The vents used were made of 18-gauge steel 55-gallon barrels with the ends cut out, and spaced two inches apart to allow for escape of air inside the pile. These vents ran crosswise of the piles and were spaced 20 feet apart.

Table 1.—Shrinkage in Weight and the amount of sugar loss in Ventilated and Non-ventilated Beet Storage Piles at Rocky Ford, Colorado, in 1948 and 1949.

	Ventilated Pile		Non-Ventilated Pile	
	1948	1949	1948	1949
Percent loss in wt.	3.8	6.10	7.01	7.50
Loss in lbs. of sugar per ton per day	0.34	0.43	0.78	0.51
No. of days storage	40	38	40	38

The samples for immediate sucrose analysis and for placement in the piles were selected as described in earlier experiments (1). The same procedure to obtain pile temperatures was used, namely; hanging stem thermometers inside ½-inch pipes which had been driven into the beet piles.

Temperatures

The effect of blowing cold night air into the beet piles at Rocky Ford was much the same as was experienced in the 1946 and 1947 experiments. In the ventilated piles, there was a rapid drop from initial temperatures of between 55 to 60° F. down to 40° F. or lower after five nights of fan operation. The average temperature of the non-ventilated pile in 1948 did not reach 40° F. until 24 days after piling while the temperature of the non-ventilated pile in 1949 was still 44.5° F. after 38 days of storage.

Sugar Losses and Weight Shrinkage

Table 1 presents the data based on the weights and sugar content of the samples which were placed in the piles.

It may be noted from the data in Table 1 that the shrinkage in weight was greatest in the non-ventilated piles and that the loss in sugar per ton per day of storage was also greater in the non-ventilated pile.

The results for the experiments at Clarksburg are presented in Table 2.

[1] Plant Pathologist and Factory Managers, American Crystal Sugar Company.
[2] The numbers in parentheses refer to literature cited.

Results presented in Table 2 show a substantial reduction in sugar losses where ventilation with cool night air is employed. It may be noted that the losses in the Clarksburg experiments are considerably higher than those obtained at Rocky Ford. This is no doubt the results of higher day and night temperatures during the beet storage period.

Discussion

Experiences in the ventilation of sugar beet storage piles at Rocky Ford and Clarksburg as well as at other locations in American Crystal territory have been favorable to the extent that in 1949 a total of 140,019 tons were handled in this manner.

Table 2.—Effect of blowing cool night air into Sugar Beet Storage piles on Sugar losses at Clarksburg, California in 1948 and 1949.

	Ventilated Pile		Non-Ventilated Pile	
	1948	1949	1948	1949
Loss in lbs. of sugar per ton per day	0.75	1.15	1.12	1.55
No. of days storage	50.1	27.0	25.3	32.1

If beets are delivered promptly from the field, and are reasonably free of trash, little difficulty is experienced in storage if they are ventilated. The length of the storage period may have to vary with the prevailing climatological conditions at a particular locality. The maximum storage period for the Clarksburg area seems to be about 50 days for ventilated beets and less than half as long for non-ventilated beets. Ventilated storage piles can be kept for much longer periods at Rocky Ford, Colorado; Mason City, Iowa, and Chaska, Minnesota.

The critical period at all locations is usually the forepart of the storage season. At this time air temperatures are highest and it is necessary that the temperature of the early storage beet piles be reduced below 50° F. as soon as possible. If this can be accomplished in the first week of storage then a minimum of ventilation is required to keep pile temperatures at a low level.

Summary

Ventilation of sugar beet storage piles has resulted in lowering of temperatures and a subsequent reduction in sugar losses over a period of four years.

Two of the important factors in the conservation of sugar in the pile are the following: Beets should go into the pile fresh and free from trash, and pile temperatures should be lowered as soon as possible.

On the basis of past results, a total of 140,019 tons sugar beets were ventilated at six factories of the American Crystal Sugar Company.

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Observations on the Dehydration of Beets after Receiving and During Storage in Northern Montana

ROWLAND M. CANNON[1]

During the past three years in the Chinook, Montana, district of the Utah-Idaho Sugar Company, there has been evidence that considerable dehydration or evaporation of moisture from beets takes place after they have been delivered to receiving stations. (See Tables 1 and 2.) It is felt that this may have been important both in fresh beets enroute to the factory in railroad cars and in beets which have been piled.

For some years, it has been felt by the author that such may be the case under certain conditions, and that the extent to which such dehydration occurs is largely dependent upon climatic and atmospheric conditions, particularly relative humidity.

It is entirely possible that the large swing toward mechanical harvest of the crop may be significant in this regard, since in most cases the time between harvest and delivery of the beets is reduced materially, and during this interim the beets are seldom laying out in windrows. This condition would decrease moisture loss in the beets before they are delivered, and might increase the opportunity for such loss after delivery.

This evaporation loss may be alarming in some respects, but it does have the advantage of making available a tremendous source of cooling capacity for storage beets if it can be utilized. The cooling potential of such evaporation may best be illustrated by example. Samples placed at the bottom of beet piles (Table 2) lost weight at the average rate of 0.2% per day during the storage period. If this loss is all moisture, water would be evaporated from the beets at the rate of 4 pounds per ton per day. Each pound of moisture so evaporated would remove nearly 1,000 B. T. U. of heat energy from the beets, or nearly 4,000 B. T. U. would be removed per ton of beets per day.

According to respiration values given by Fort and Stout[2], this rate of evaporation would absorb the heat given off by the respiration of beets at about 70° F. For beets at 50° F., it would absorb the heat of respiration and require enough additional heat to cool the beets at the rate of about one degree F. per day. In other words, such a rate of dehydration can do the same job of cooling which is requiring elaborate and expensive air-conditioning installations under different atmospheric conditions.

Following observations made in 1947, a number of modifications was made in piling procedures in order to try to build piles which would best utilize the potential cooling power of dehydration. It was felt that piles

[1] Agricultural Superintendent, Utah-Idaho Sugar Co., Chinook, Mont.
[2] Fort and Stout. Respiratory Heat of Sugar Beets and its Influence on the Practical Harvesting and Storage Problem. U. & I. Cultivator, Vol. 6, No. 3, October, 1946, pp. 10-13.

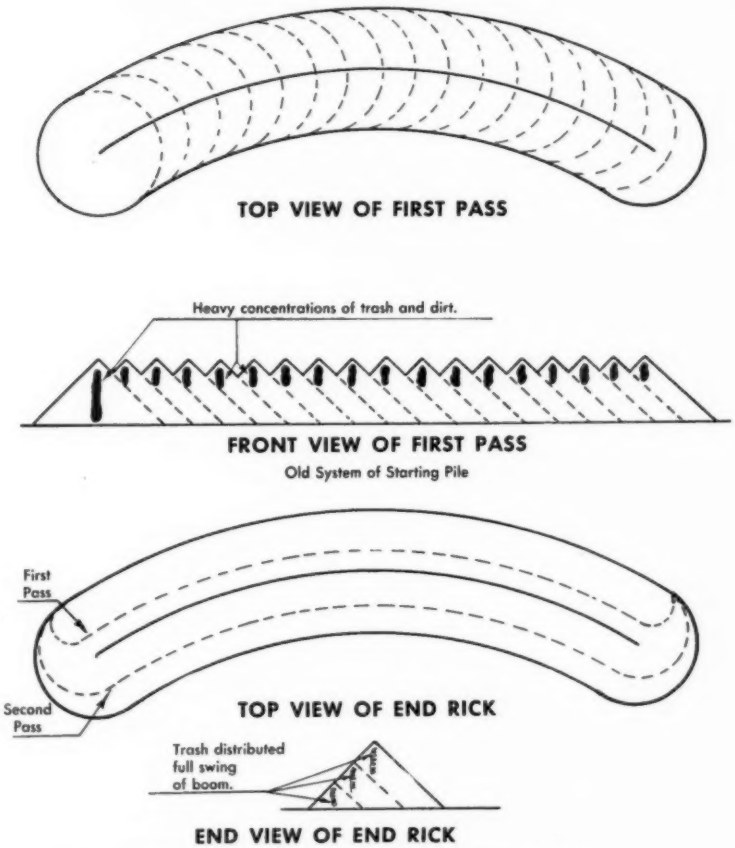
TOP VIEW OF FIRST PASS
Heavy concentrations of trash and dirt.
FRONT VIEW OF FIRST PASS
Old System of Starting Pile
First Pass
Second Pass
TOP VIEW OF END RICK
Trash distributed full swing of boom.
END VIEW OF END RICK

Figure 1. Diagram of old and new methods of starting piles.

should be so made that atmospheric air could reach all parts of the pile freely. In order to accomplish this objective, two fundamental factors were considered: (1) the elimination of any concentrations of trash or dirt at any places in the pile, and (2) the height and width of the pile.

A number of procedures was adopted to accomplish these purposes as follows:

1. **Wherever possible, new screens were installed on pilers to do a more effective job of screening out dirt and trash.**
2. **Maximum care was exercised with growers to eliminate dirty loads and generally reduce trash and dirt in beets delivered, and, of course, frozen beets were not piled under any consideration.**

Table 1.—Sugar Content Comparisons at Chinook, Montana, Factory Campaigns 1947, 1948 and 1949.

Year	Average Sugar Content of Beets Sliced Directly after Receiving	Estimated Average Sugar Content of Beets as They Were Piled	Average Sugar Content of Beets Sliced from Piles	Estimated Average Sugar Content of All Beets as Received	Average Sugar Content of All Beets Sliced	Number of Piles	Percent Total of Beets Piled	Average Number of Days in Pile
		[1]		[1]				
1947	16.56	16.76	16.97	16.66	16.79	9	55%	46
1948	15.74	15.73	16.26	15.71	16.03	7	55%	39
1949	15.43	15.34	15.82	15.37	15.56	5	34%	33

[1] These values are cossette test equivalents, since they were determined by assuming that the beets piled during a given period were of the same average sugar content as the beets sliced directly after receiving during the same period.

3. **The method of starting a pile was changed. The practice had been to start out by building up a cone of beets to the height desired, then swinging the boom and carrying this pass on around to the desired width. This system was modified as follows: The boom was lowered to the lowest position and beets were discharged in an arc with a rick about six feet high being built. The boom was swung over this arc three or four times in order to build up to this height. The boom was then raised to about 11 feet and the piler moved back to the point where beets would just flow over the back surface of the first rick when the pile reached a height of 11 feet.**

   Several swings of the boom were made in reaching the 11-foot height. The boom was then raised to 15 feet, the piler moved back, and the process repeated. Whenever the boom is held in one place a mechanical separation of beets from dirt and trash results. For the most part, the dirt, trash and muddy and small beets stay where the material discharged from the boom hits the pile, and the larger, cleaner beets roll down the sides. Where the boom is held stationary for a period, a concentration of trash and dirt results. The old system and new system of starting a pile are illustrated in Figure 1.

4. **Pile heights were limited to 15 feet wherever piling areas would permit. The quantity of trash and dirt accumulated in any place in the pile is dependent on the length of time material is discharged from the boom to that place. By reducing the height of the pile from 20 to 15 feet, these concentrations were reduced accordingly.**

5. **Provisions were made for continuous or near-continuous movement of booms. Where volume was heavy, a mechanism was installed to provide continuous oscillation of the boom back and forth. Where smaller pilers with hand cranks for moving the boom were used, extensions were provided on the cranking mechanism so the operator could move the boom from the back end of the piler. In such cases the boom was swung back and forth over the face of the pile**

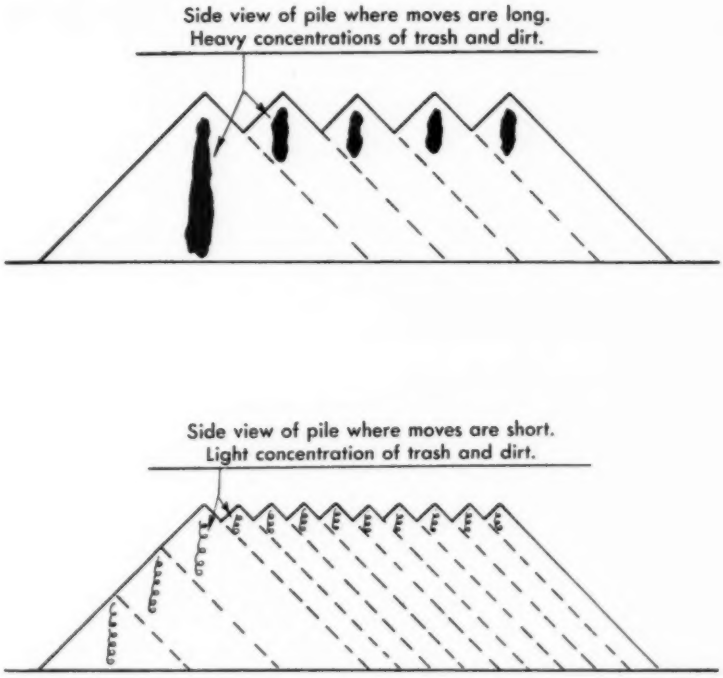
Side view of pile where moves are long.
Heavy concentrations of trash and dirt.
Side view of pile where moves are short.
Light concentration of trash and dirt.

Figure 2. Diagram of effect of short and long moves on trash and dirt concentrations in pile.

two or three times between moves. Particular care was taken to spread out loads containing excessive amounts of dirt and loads of small beets. Where the boom was left stationary at the ends of the swing to fill out the corners of the pile, an attempt was made to have beets from clean loads going over it.

6. The distance the piler moved back was shortened. Wherever volume was not too heavy, 3-foot moves were used. Moves of four feet were made where volume was so heavy as to cause receiving delays with 3-foot moves. Short moves reduce the volume of dirt and trash going into one place, as shown in Figure 2.

7. Piles were immediately leveled on top to reduce the possibility of channeling air up through the pile.

8. Piles were made as narrow as possible. In each case, the cubic content of the maximum estimated tonnage to be piled was determined and the width of the pile was determined by correlating this cubic content with the full length of piling ground available.

Some of these procedures were used in 1947; others were added in 1948; and in 1949 they were followed very carefully. A study of sugar contents and days of storage as listed in Table 1 would indicate that the rate of dehydration of piled beets was increased each year. While results as far as condition of piles is concerned are not conclusive, it might be observed that in both 1948 and 1949 all of the beets came out of the piles in excellent condition with practically no regrowth and no evidence of spoilage.

Table 2.—Shrinkage of Samples Placed in Piles.

Placement in Pile	Average No. of Days in Pile	Average Weight of Samples into Pile	Average Weight of Samples Out of Pile	Average Percent Shrink	Average Percent Shrink per day Storage
Near Bottom	41	86.71	79.58	8.22	0.200
At Top	41	87.96	65.71	25.30	0.617

A question may arise as to the effect of high dehydration on shrink between beets received and beets sliced. This matter certainly presents a problem worthy of further study. There are many factors involved and the relative importance of each needs evaluation. The question arises as to which is the most costly: the loss of moisture from high dehydration or the weight losses from increased sugar losses from respiration and other weight losses which would be encountered where dehydration rate are lowered and pile temperatures are higher. While a number of other factors can and probably did affect shrink, it might be observed that, of the three years studied, the highest shrink was encountered in 1947 where the indicated rate of dehydration was lowest, and the lowest shrink was encountered in 1949 where the indicated rate of dehydration was highest.

Conclusions

In areas where the humidity of atmospheric air is normally low during storage periods, there is evidence of considerable dehydration of beets after they are received and particularly in storage. If storage conditions can be modified to take advantage of the cooling power of this evaporation of moisture, it has a tremendous potential as far as cooling piles is concerned. It is felt that much was done at Chinook to accomplish this end in the past two years and that it resulted in reduced storage losses and an improvement in the condition of beets from storage.

This work is of a very preliminary nature in the study of the problem and it certainly seems to be of sufficient economic importance to warrant concentrated detailed study.

Heat and Moisture-Transfer Studies in Relation to Forced Ventilation of Insulated Columns of Sugar Beets

MYRON STOUT[1]

The application of forced ventilation with cool night air to piles of sugar beets is comparatively new. The first test conducted by Mr. C. A. Fort and the writer probably introduced more new questions than it answered, although it did introduce a simple means of reducing storage losses. Some of the questions introduced were as follows:

How much air is required for various conditions?

What is the resistance to air flow in a pile of beets?

What kind of temporary or permanent air ducts should be used?

What are the economic limits of height in relation to commercial piling practice?

How much cooling can be expected from evaporative cooling?

Should the air be humidified before being forced into the pile?

At what temperature and for how long can cold air be forced into a pile of beets without producing freezing injury?

Are walls around commercial piles beneficial and if so are they worth the cost?

Some of these questions now have at least tentative answers which have been secured by many different men and organizations who have pooled all information to the common problem.

Some of the questions require special equipment for their solution and the Beet Sugar Development Foundation and the U. S. Department of Agriculture have cooperated in providing equipment and personnel to study them. Some of this equipment at Salt Lake City has been used by the writer in an attempt to secure basic information which is difficult to obtain in commercial installations.

The insulated columns, described in a previous report[2], are three feet inside diameter and 24 feet high. Each column was filled with three tons of beets. Beet temperatures were recorded continuously at the 0, 4, 8, 12, 16, 20 and 24-foot levels. Air temperatures and humidities were measured periodically at the 0, 8, 16 and 24-foot levels by withdrawing samples through a 1-inch pipe, a short, flexible gas mask tube, and through a Friez, electrically-ventilated psychrometer.

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[1] Physiologist, Division of Sugar Plant Investigations of the Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

[2] Proceedings American Society of Sugar Beet Technologists, pp: 635-640, 1948.

Table 1.—Forced ventilation of columns of beets with humidified vs. normal air from 11:00 p.m. to 7:00 a.m. 10/13/48. Ventilation rate 64 C.F.M. or 21 C.F.M./ton

	Temperature			Moisture		Heat balance			
			Rel.	Per 1,000	Total	Cooling			Beets
Height	Beets	Air	hum.	cu. ft. air	evap.	Air	Evap.	Total	cooled
Ft.	°F.	°F.	%	Lbs.	Lbs.	B.T.U.	B.T.U.	B.T.U.	B.T.U.
SOUTH COLUMN 30,720 cu. ft. humidified air:									
0	46.8	49.0	87.2	0.491	.....	.....	.....	.....	
8	51.5	50.4	95.5	0.564	2.24	834	2,380	3,214	
16	56.2	53.8	97.0	0.649	2.61	2,026	2,773	4,799	
24	61.0	56.0	105.0	0.754	3.23	1,311	3,432	4,743	
Total or difference		7.0		0.263	8.08	4,171	8,585	12,756	12,642
Beets were cooled an average of 2.59 —0.14 = 2.45° F.									
NORTH COLUMN 30,720 cu. ft. normal air:									
0	48.0	51.2	57.8	0.351	.....	.....	.....	.....	
8	51.5	50.9	94.8	0.569	6.70	—179	7,119	6,940	
16	58.4	55.1	97.0	0.676	3.29	2,503	3,496	5,999	
24	63.8	58.0	100.8	0.774	3.01	1,728	3,198	4,926	
Total or difference		6.8		0.423	13.00	4,052	13,814	17,865	15,377
Beets were cooled an average of 2.92 + 0.06 = 2.98° F.									

The flow of air was measured with a 4-inch anemometer placed in the cap of the columns. Air-flow adjustment was made by regulating the speed of the blowers and the openings in the caps of the columns.

During some of the earlier studies heat balance data checked quite well because natural cooling through the walls of the closed columns was about equal to the respiratory heat of the beets. During later studies at cooler temperatures, however, it was necessary to determine the temperature change of the beets when the closed columns were exposed to a similar outside temperature for like periods. These temperature-corrections were applied to the average cooling obtained during ventilation tests. Ventilation periods

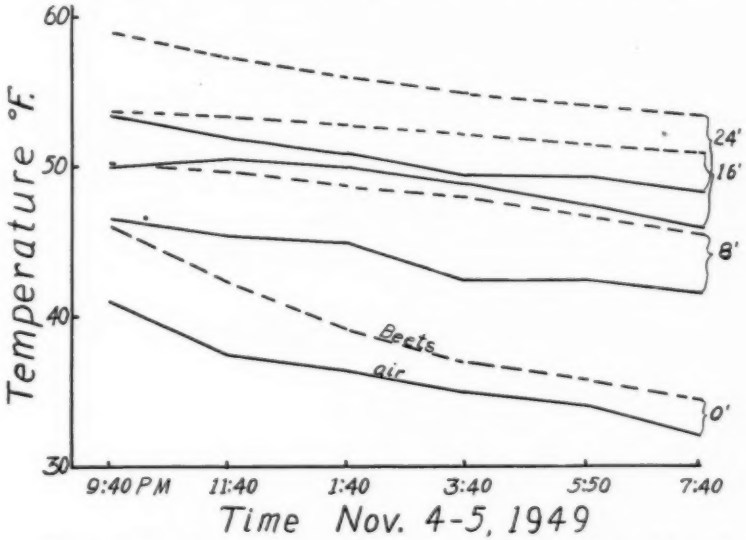

Figure 1. Relation of the temperature of beets to that of the ambient air during a period of forced ventilation at a rate of 60 C. F. M. or 20 C. F. M. per ton of beets.

were usually from seven to twelve hours during nights when air temperatures remained fairly constant. Air-temperature and humidity values at each check-point in the column were measured periodically from four to seven times during the ventilating period.

To simplify tabulation average values for beet and air temperatures, relative humidity and moisture content of the air are given at the 0, 8, 16 and 24-foot levels only. Total pounds of moisture evaporated between the various levels in the columns are obtained by subtracting the pounds of water per 1,000 cubic feet entering a lower position from that at the position in question and multiplying by the thousands of cubic feet of air.

Some of the values used in the calculations may be listed as follows: Heat capacity per 1,000 cubic feet of air per ° F. = 19.4 B.T.U. This value

Table 2.—Forced ventilation of columns of beet at different rates of ventilation. 60, 90 and 120 C.F.M.

Height	Temperature		Rel.	Moisture		Heat balance			
				Per 1,000	Total	Cooling			Beets
	Beets	Air	hum.	cu. ft. air	evap.	Air	Evap.	Total	cooled
Ft.	°F.	°F.	%	Lbs.	Lbs.	B.T.U.	B.T.U.	B.T.U.	B.T.U.
NORTH COLUMN Nov. 4-5. 10 hrs. 60 c.f.m. = 36,000 cu. ft. of air:									
0	39.1	36.0	91.0	0.318	.....	.....	.....	.....	
8	48.2	43.9	106.3	0.501	6.588	5,517	7,000	12,517	
16	52.5	48.8	97.7	0.545	1.584	3,422	1,683	5,105	
24	55.8	50.7	93.3	0.558	0.468	1,327	497	1,824	
Total or difference		14.7			8.640	10,266	9,180	19,446	22,085
Beets were cooled an average of 5.34 — 1.06 = 4.28° F.									
NORTH COLUMN Nov. 14-15. 10 hrs. 90 c.f.m. = 54,000 cu. ft. of air:									
0	38.2	35.2	91.5	0.311	.....	.....	.....	.....	
8	45.2	40.8	105.2	0.442	7.074	5,867	7,517	13,384	
16	48.8	44.7	102.7	0.494	2.808	4,086	2,984	7,070	
24	51.2	46.5	98.2	0.507	0.702	1,886	746	2,632	
Total or difference		11.3			10.584	11,839	11,247	23,086	24,562
Beets were cooled an average of 5.64 — 0.88 = 4.76° F.									
NORTH COLUMN Dec. 6-7. 10 hrs. 120 c.f.m. = 72,000 cu. ft. of air:									
0	35.7	35.0	72.5	0.244	.....	.....	.....	.....	
8	38.7	36.8	97.2	0.351	7.704	2,514	8,186	10,700	
16	42.6	40.3	96.8	0.399	3.456	4,889	3,672	8,561	
24	45.5	41.9	95.2	0.416	1.244	2,235	1,301	3,536	
Total or difference		6.9			12.384	9,638	13,159	22,797	20,382
Beets were cooled an average of 4.66 — 0.71 = 3.95° F.									

was used without correction for moisture content, temperature or pressure of the air. Heat of evaporation of water = 1,062.6 B.T.U. per pound. Specific heat of beets = 0.86 x 6,000 = 5,160 B.T.U. per ° F. for the beets in one column. The average velocity of the air passing through the columns filled with beets may be calculated by multiplying the total cubic feet of air per minute by 0.35. When ventilating at 65 C.F.M., the average velocity is 21 feet per minute.

It is evident from the data in Table 1 that the heat and moisture transfers to the ambient air are rapid. After passing through an eight-foot layer of beets the air was nearly saturated with water vapor, and the degree of saturation at a given point above eight feet was apparently affected more by the thermal gradient of the layers of beets than by the initial humidity or velocity of the air at the rates studied.

The fine spray used for humidifying the air to the south column delivered only about six gallons of water per hour. This water was relatively warm (59° F.), however, and greatly reduced the amount of evaporative cooling which would have been obtained with cool water. Although the normal air to the north column gave up heat to the first ton of beets, the net cooling of the first ton of beets was more than twice as great as that obtained in the south column which was ventilated with humidified air. The data in Table 1 show that, even after the air had reached nearly 100% relative humidity, more heat was removed by the evaporation of moisture than by the temperature rise of the air as it passed through successively warmer layers of beets. The data in Table 1 and many other similar cooling runs showed that the water used to humidify the air for ventilating beets should be cool. If cool water is not available it should be re-circulated to the humidifying equipment. The consistently greater absorption of heat by evaporation, even after the air reached near saturation, offers an explanation as to why small amounts of air have greatly reduced storage losses in some storage tests. Removal of surplus moisture also reduced effectively rotting due to attack by fungi.

Equipment for humidifying air for ventilation of piles of beets may justify the expense in areas where the temperature is high and the humidity is low but the use of air having a dew point higher than the temperature of the bottom beets involves the risk of increasing attack by fungi by condensing water on the beets. It is very doubtful if humidifying equipment is justified in cold climates because of the difficulty involved in preventing freezing of pipes and plugging of filters, or other equipment for removing spray, with ice.

The data in Table 2 show that, even with much greater volumes of air than are used in commercial installations, the transfer of heat and moisture to the ambient air was nearly as rapid as at lower rates of ventilation. The temperature differential between the beets and air at the top of the column was more greatly affected by the temperature difference between beets in the bottom and top of the column than by the rate of ventilation. The results of many tests showed that the air to beet temperature differential was about 3° F. when the top to bottom differential was about 9° F. This relationship appeared to be roughly linear. The air to beet differential at the top was about ⅓ of the top to bottom beet temperature differential.

The data in Table 2 also show that air cooling accounted for a greater part of the total heat removed from the beets than was shown in Table 1 where air and beet temperatures were warmer. However, the total calculated values checked reasonably well with the heat removed from the beets. By means of the data available it is possible to estimate the cooling which should occur in the internal parts of piles of beets by the use of forced ventilation. The calculated cooling should represent cooling in addition to that due to any draft induced in the pile by the forced movement of air and should apply to any given conditions of temperature and humidity.

Example: To estimate the heat removed from a pile of beets 20 feet high which has an average temperature of 58° F., bottom beets at 54° F. and top beets at 63° F., by ventilating with air at 38° F. and 62% relative humidity at a rate of 20 C. F. M. per ton of beets.

One ton of beets occupies about 50 cubic feet and has about 40% voids. One ton of beets will represent an area of 2.5 square feet of the pile with an average of 1 square foot of air space. The average velocity of the air will be 20 feet per minute. The air will probably come out the top of the pile at 60° F. and 98% relative humidity. The heat absorbed by the air will be: (60 — 38) x 19.4 x 1.2 = 512.16 B. T. U. per ton per hour. The evaporative cooling will be:

Air leaving top 0.821 x 0.98 = 0.8046 lbs. H_2O per 1000 cu. ft.[2]

Air entering bottom 0.378 x 0.62 = 0.2344 lbs. H_2O per 1000 cu. ft. (0.8046 — 0.2344) x 1.2 x 1062.6 = 727.07 B. T. U. per ton per hour.

The respiratory heat of beets at 58° F. is about 81 B. T. U. per ton per hour[3].

The net cooling will be 512.16 + 727.07 — 81. = 1158.23 B. T. U. per hour.

This should cool the beets an average of $\frac{1158}{(2000 \times 0.86)} = 0.67°$ F. per hour.

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[2] Table 1, p. 638 Proceedings American Society of Sugar Beet Technologists, 1948.
[3] Table 1, p. 12 U and I Cultivator, October, 1946.

Effects of Wilting, Drought, and Temperature Upon Rotting of Sugar Beets During Storage[1]

JOHN O. GASKILL[2]

Storage of sugar beets, *Beta vulgaris* L., in large piles at receiving stations between time of harvest and processing is a common practice in most sugar beet regions of the United States. Such storage ranges from a few days to 3 or 4 months and is advantageous both to growers and processors, but its usefulness is limited seriously by loss of sugar through the natural process of beet respiration and by rotting caused by microorganisms. In some storage piles the former type of loss predominates. In others, rotting caused by microorganisms is by far the more important. These organisms break down the normal cell structure of the roots, utilizing the sugar for their own growth and respiration and producing heat which, together with that evolved by the respiration of the beets, tends to raise pile temperature and thus accelerate both beet respiration and rate of rotting. This vicious cycle leads frequently to excessively high temperature, resulting in such rapid rotting that large sections of a pile are rendered unfit for use within a few days or weeks. In fact, in more than one instance, an entire pile of thousands of tons has been totally lost in this way.

Rotting of sugar beets during storage is influenced by a wide variety of factors. High storage temperature has long been recognized as a serious hazard, and freezing of roots between time of lifting and piling is generally regarded as an extremely important factor predisposing them to attack by microorganisms. Larmer (4)[3] found that poor soil fertility—especially shortage of phosphorus—has a detrimental effect on keeping quality. Inadequate moisture during the growing season also was found to be conducive to rot. Tompkins and Nuckols (5, 6) showed that hook injury made during harvest contributes to the development of rot and that low topping also is detrimental. Some years ago it was observed by the writer that storage rot losses were more severe among mother beet roots which had become wilted in the field after lifting than among roots which were stored promptly. A similar observation was made by Stout and Fort (1) in connection with respiration studies, and such a tendency has been suspected by sugar company agriculturists in recent years.

The experimental work reported in this paper was begun at Fort Collins, Colorado, in 1948 for the purpose of obtaining more detailed in-

[1] Report of a study made under Research and Marketing Act of 1946. Colorado A & M Agricultural Experiment Station Scientific Journal Series No. 320.

[2] Pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, Fort Collins, Colorado. Acknowledgment is made to the Botany and Plant Pathology Section of the Colorado A & M Agricultural Experiment Station and to the Beet Sugar Development Foundation for facilities used in connection with these investigations, and to Dr. G. H. Coons of the Division of Sugar Plant Investigations for helpful suggestions in connection with the planning of the experiments.

[3] Numbers in parentheses refer to literature cited.

formation regarding the importance of some of the factors listed above insofar as rot loss is concerned. Data pertaining to certain other factors are presented by the author in contemporary papers (2, 3).

STORAGE METHODS

Samples of sugar beet roots were hand topped, avoiding hook injury, and stored in shallow wooden boxes in 2 insulated rooms held at 65° F. and 45° F. (± 2° F.). Continuous forced ventilation was provided, the air in each room was circulated constantly, and relative humidity was maintained at a level high enough to prevent excessive evaporative loss in weight of healthy roots. Average relative humidity was approximately 93 percent in each room during the 1948-49 storage season and about 97 to 98 percent

Table 1.—Effects of pre-storage drying upon keeping quality of sugar beet roots stored for 13 and 19 weeks at 65° F. and 45° F., respectively; results given as averages of duplicate samples of 18-19 roots each. Fort Collins, Colorado, 1948-49.

Drying period in sunlight	Loss in weight during drying period	Loss in weight during storage		Weight of rotted tissue at end of storage	
		65° F.	45° F.	65° F.	45° F.
	Percent	Percent	Percent	Percent	Percent
½ hr. (check)	----	11.7	2.8	11.8	4.3
1 day	6.0	12.9	0.9	31.9	11.4
2 days	9.9	18.7	2.6	65.6	27.3
4 days	15.4	26.1	3.5	87.5	34.2
L. S. D. (5-percent point)				11.7	6.3

during the following season. Atmospheric carbon dioxide determinations made periodically during the first storage season indicated that the maximum concentration reached in either room was less than 0.5 percent.

The percentage of rot in each sample was determined at the end of storage by separating and weighing the rotted and healthy tissue. Storage periods during the fall and winter of 1948-49 were approximately 3 and 4½ months for the 65° and 45° rooms, respectively. In the 1949-50 season, rot determinations were made for both rooms 2 months after harvest, in order to permit temperature comparisons; also at the end of storage periods of approximately the same length as those of the first year. Of the 1949-50 results, only the 2-months' storage data were obtained in time to be included in this paper.

WILTING OF ROOTS AFTER HARVEST 1948-49

On October 20, 1948, 16 comparable samples of freshly harvested sugar beet roots of a commercial variety—18 to 19 roots per sample—were washed, drained, weighed, and divided into 4 groups of 4 samples each, which were then dried out of doors in direct sunlight for ½ hour (check), 1 day, 2 days, and 4 days, respectively. Weather was relatively dry and sunny. The samples were covered at night to prevent freezing, reweighed after drying, and divided between the 2 storage rooms—2 samples per room for each treatment. Rot weighings were made after approximately 13 weeks' storage at 65° and 19 weeks at 45°.

The results as presented in Table 1 and Figure 1 show a very striking trend from relatively little rot for roots dried ½ hour to 7 or 8 times as much rot for roots which had lost 15.4 percent of their weight during 4 days' pre-storage drying. Each successive increase in drying time, beyond the ½ hour given the check treatment, was accompanied by a statistically significant increase in percentage rot at both temperatures.

1949-50

On October 12, 1949, a similar experiment was begun using 40 samples of 18 roots each. Weather was dry and sunny on the whole, and the samples were handled in about the same way as in the preceding experiment with one important difference. After 2 months' storage each sample was weighed and divided as nearly as possible into two 9-root samples equivalent in

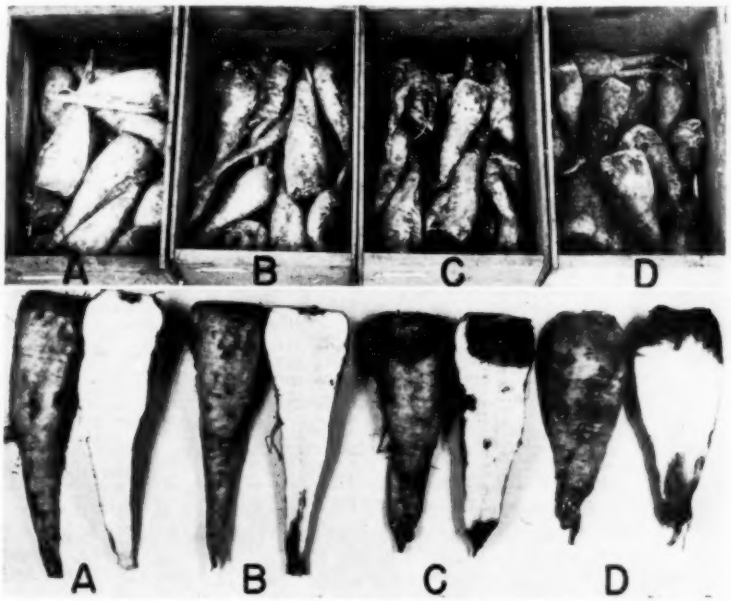

Figure 1. Sugar beet roots showing effects of pre-storage drying upon keeping quality. A, Dried ½ hour; B, Dried 1 day; C, Dried 2 days; D, Dried 4 days. Top—samples after 3 months' storage at 65° F. Bottom—representative roots from samples stored 4 months at 45° F.

apparent amount of rot. One was used for immediate determination of percentage rot and the other was returned to storage for later rot determination.

The data obtained after 2 months' storage are given in Table 2. These results confirm the findings of the preceding experiment insofar as the disastrous effects of field wilting are concerned. In addition they show consistent contrasts between storage rooms with average percentage rot in the

65° room amounting to approximately 7 times that occurring at 45°. Since storage conditions in the two rooms were very nearly identical, except for temperature, that factor is considered as largely responsible, basically, for the difference in percentage rot.

DROUGHT

1948-49

In a field near Ault, Colorado, in 1948, a long 8-row strip of a commercial variety which had been well watered until August 27 or 28 was divided into 6 sections, in each of which rows 4 and 7 were used as a pair of plots. In section 1, the furrow on each side of row 7 was irrigated on September 13 and October 5, row 4 receiving no irrigation after August 27 or 28. In section 2, row 4 was irrigated, number 7 remaining dry, and this same alternating system was used throughout the other 4 sections. Weather was dry from the time of the last general irrigation until after harvest. At harvest (October 12) the soil was quite moist in the series of "wet" plots and very dry in the other series. In the dry plot in sections 4, 5, and 6, foliage was somewhat wilted and a small percentage of the roots were rather flaccid. In the other 3 sections drought effect appeared to be much less severe and

Table 2.—Comparison of keeping quality of sugar beets dried after harvest for varying periods and stored for 2 months at 65° F. and 45° F. Percentage-rot data are given as averages, each based on five 9-root samples; other storage data are averages from five 18-root samples each. Fort Collins, Colorado, 1949.

Drying period in sunlight	Loss in weight during drying period	Loss in weight during storage		Weight of rotted tissue at end of storage	
		65° F.	45° F.	65° F.	45° F.
	Percent	Percent	Percent	Percent	Percent
1 hr. (check)	.....	5.9	4.7	2.3	0.5
1 day	2.9	8.5	4.3	15.2	2.1
2 days	8.1	8.9	3.5	30.5	5.2
4 days	13.2	13.5	4.2	52.3	6.8
L. S. D. (5-percent point)				9.9	1.7
General mean				25.09	3.65

no flaccid roots were found. Seventy-five consecutive roots were dug carefully by hand in each plot and divided into 3 comparable samples of 25 roots each. After being washed and weighed, sample 1 was analyzed for sucrose percentage and samples 2 and 3 were stored at 65° and 45°, respectively.

With harvest performance of the wet treatment taken as 100 percent, the dry treatment results were as follows: average weight per root 92.3, percentage sucrose 106.3, and gross sucrose per root 98.8. These figures indicate an appreciable but largely compensating effect of drought upon root size and sucrose percentage, with negligible effect upon yield of gross sucrose.

As shown in the summary of storage results (Table 3), the average percentage rot for the dry plots was significantly greater than that obtained for the wet plots—data from both temperatures combined.

1949-50

A randomized-block field experiment with 3 treatments, 6 replications, and 6-row, 40-foot plots was laid out in 1949 in a field of a commercial

sugar beet variety near Wellington, Colorado. All plots were watered alike until August 29-30, the time of the last general irrigation. Thereafter, check plots received no more irrigations, and treatments W1 and W2 were irrigated once and twice, respectively. Weather was very dry after the last general irrigation, and by harvest time foliage in check plots wilted considerably in midday. There was relatively little wilting in plots of W1 and

Table 3.—Effects of moderate drought late in the season upon storage rot of sugar beets; results given as 6-plot averages. Fort Collins, Colorado, 1948-49.

Storage temperature	Storage period	Wt. of rotted tissue at end of storage	
		Well irrigated	Soil dry at end of season
°F.	Days	Percent	Percent
65	96	33.9	43.3
45	139	14.4	28.8
Analysis by Student's method (both temperatures combined):			
Mean difference		11.87[1]	
t		2.30	
P		< .05	

[1] A significant difference, based on the 5-percent point.

none in W2. Roots were somewhat less turgid in check plots than in plots of the other 2 treatments. The effect of drought upon harvest performance in check plots, based on results obtained for the W2 treatment, was about like that recorded for the preceding experiment. Yields of gross sucrose of 2.187, 2.096, and 2.223 tons per acre for check, W1, and W2 treatments, respectively, did not differ significantly.

Four samples of 25 roots each were obtained from each plot on October 3 for storage comparisons. Border effect was eliminated and special care was taken to avoid puller injury. Adhering soil was removed by hand insofar as practicable without apparent injury to the tap roots, and the samples were placed in storage at once without washing, and containing approximately 1.2, 1.9, and 1.9 percent soil for the check, W1, and W2 treatments, respectively. The 4 samples from each plot were divided between the 65° and 45° storage rooms.

After 2 months' storage, the percentage rot was determined for one sample per plot in each room, adhering soil disregarded. The summarized results (Table 4) fail to show significant effects of drought upon rot development. Temperature effects are shown strikingly, average percentage

Table 4.—Comparison of storage rot development among sugar beets matured under differing soil moisture conditions and stored for 2 months at 65° F. and 45° F.; results presented as 6-plot averages. Fort Collins, Colorado, 1949.

Treatment number	Irrigations after Aug. 29-30[1]	Wt. of rotted tissue at end of storage	
		65° F.	45° F.
	Number	Percent	Percent
Check	0	9.54	0.55
W1	1	7.92	0.69
W2	2	7.85	0.44
L. S. D. (5-percent point)		9.72	0.49
General mean		8.44	0.56

[1] All plots irrigated alike up to and including August 29-30.

rot of 8.44 for the 65° room amounting to 15 times that occurring at 45°. Figure 2 is presented in an attempt to illustrate representative types of rotting occurring at the 2 temperatures, irrigation treatment disregarded—roots taken from supplementary samples which had been washed before being stored.

The above results indicate that, under some conditions, moderate drought late in the season tends toward greater susceptibility to storage rot. These

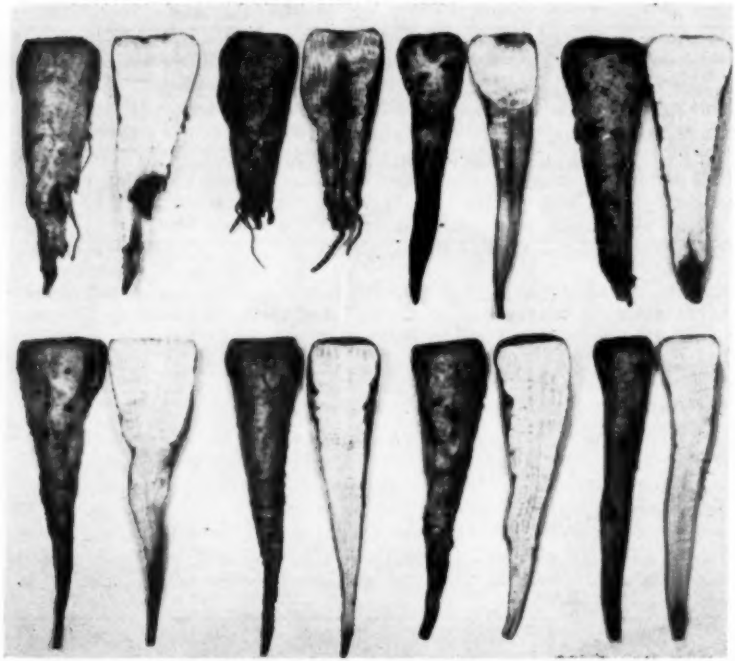

Figure 2. Exterior and interior view of sugar beet roots after 72 days' storage, showing effects of temperature on development of storage rot. Top, 65° F.; bottom, 45° F. Photographed by Beet Sugar Development Foundation, December 14, 1949.

findings are in agreement with the results obtained by Larmer (4) from an experiment in which low-moisture plots were irrigated only 3 times throughout a dry season as contrasted with plots irrigated every 2 weeks from June 14 to September 15, inclusive.

SUMMARY

Samples of topped sugar beet roots were stored for periods ranging from 2 to 4½ months, approximately, under conditions of high humidity, forced ventilation, and continuous circulation of air, with 2 temperature

levels—65° F. and 45° F., approximately. At the end of storage the percentage of rot in each sample was determined by separating and weighing the rotted and healthy tissue.

Two years' results from replicated experiments showed conclusively that wilting of washed roots out of doors in dry, sunny weather has very disastrous effects upon keeping quality. Percentage rot was relatively low in check samples (dried ½ to 1 hour), becoming progressively greater for 1, 2, and 4 days' drying and, for the latter exposure, ranging from 7 to 23 times that obtained for the checks.

In 1 year's results the average percentage rot found, after 3 to 4½ months' storage, in samples taken from plots in which moderate drought conditions had existed late in the season, was significantly greater than that occurring in samples from well watered plots. In the following year the differences between similar treatments, in percentage rot, were negligible at the end of 2 months' storage.

Influence of storage temperature upon rotting was shown strikingly by results obtained from 2 large sets of root samples, each set divided between 2 storage rooms and held for 2 months with relative humidity averaging approximately 97-98 percent. Average rot percentages for the 2 groups of samples stored in the 45° room were 3.65 and 0.56, whereas the comparable percentages for 65° storage were approximately 7 and 15 times as great, respectively.

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Respiration and Spoilage Studies Employing a Modification of Method Developed by Stout and Fort

R. T. NELSON AND R. R. WOOD[1]

The advantage in minimizing the losses accruing between harvest and the processing of sugar beets is apparent. Already, much has been learned and put into practice regarding the handling and storage of beets to reduce sugar loss. In contrast, however, very little direct effort has been made to evaluate and improve the anatomical and physiological properties of the beet root which affect storage quality and which are unquestionably governed by genetic complexes not yet unified by selection except that coincident with the improvement of other characters.

A prerequisite for embarking on a breeding program for the improvement of a desired quality is the establishment of a test which will itself measure or correlate closely with the specific character or characters under study. The work of Stout and Fort provides a method which permits measurements of storage losses of individual samples held under comparable environmental conditions. This paper reports some modifications in technique and the results obtained in preliminary evaluations on storage quality of different lines of beets.

Methods and Materials

The storage quality of several varieties of sugar beets was investigated in the fall of 1949, using measurements of oxygen consumption as a criterion. The method of Stout and Fort[2] was used except for the water-oxygen displacement method used by them in feeding and measuring oxygen into the barrels. Oxygen measurements in the course of this study was read directly from a wet test gas meter. A balloon instead of a glass carboy was used for holding the 24-hour supply of oxygen for each barrel (see Figure 1). The distribution line was used for oxygen instead of water. A water trap was inserted, however, in the connection of the balloon with the barrel so that air from the barrel would not get into the balloon.

A normally open solenoid valve was used in the distribution line ahead of the meter and controlled by a mercury switch which in turn was operated by a bellows. The bellows was not used as an intake or to influence the pressure in the line, but merely to reflect the pressure in the line and to open and close the mercury switch. The mercury switch was adjusted to close when the oxygen pressure in the line equaled eight-tenths of an inch of water and to open again at six-tenths. The balloons were filled individu-

[1] Agronomists, The Great Western Sugar Company, Agricultural Experiment Station, Longmont, Colorado.

[2] Stout, Myron. Studies on the respiration and spoilage of sugar beets. Proc. Amer. Soc. Sug. Beet Tech., 1950.

ally to the same relative pressure each morning by merely opening the inlet to the balloon and closing the outlet. The difference in meter reading at start and end of fill represented the volume of oxygen, at the existing temperature and pressure, which was drawn into the barrel during the previous 24-hour period. By calculation one can convert to absolute values taking into account atmospheric pressure changes during the period, but for a comparative ranking of the storage qualities of two or more varieties run simultaneously this is not necessary. For publication, calculations were made to absolute values from the average of readings obtained during each period of one week.

The beets for study were taken from the border rows of a single variety test. The beets used in the first test were dug, topped (by cutting off the usual portion of the crown), and washed November 1, then stored outside in burlap bags until placed in sealed drums on November 5. Beets used in the second test were dug November 2, trimmed as mother beets, washed, and placed in crates in the root storage cellar until space was available to run respiration rates. The crowns were cut off before the beets were weighed and placed in the sealed drums. The size of samples for the first test was 110 pounds and for the second test 100 pounds, all weights being accurately made. The average weight per beet exceeded two pounds.

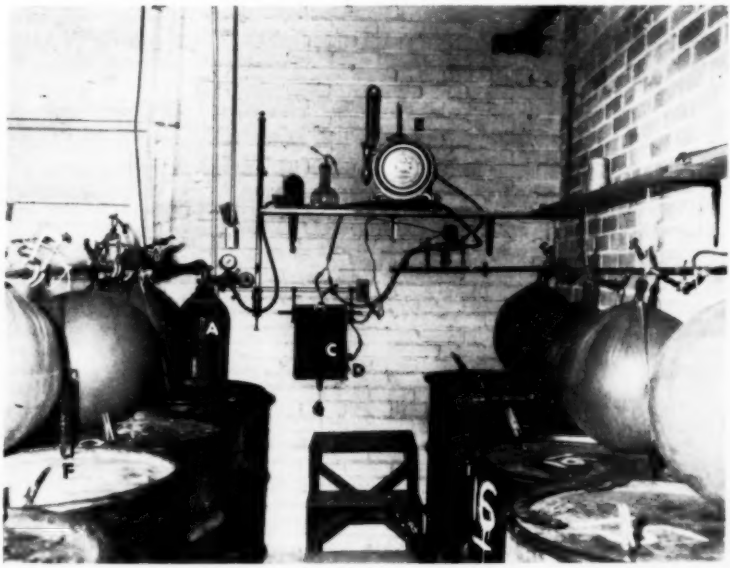

Figure 1. A—Oxygen tank and pressure-reducing valve. B—Solenoid valve. C—Bellows. D—Mercury switch. E—Gas meter. F—Water trap.

Results and Discussion

The results of the first test begun November 5, 1949, are given in Table 1. Nine varieties and two replications were used in the first test.

Table 1.—Oxygen used by different sugar beet varieties stored six weeks at 70° F., and calculated minimum sucrose loss (mean of two samples).

Variety	0_2 at Vo used per 100 pounds beets per day (cubic feet)	0_2 used per kg. beets per hour (mg.)	Min. sucrose loss per ton per day (calc.) (pounds)
C455	.3187	11.85	.51
GW201	.3291	12.23	.52
B389	.3320	12.34	.53
GW85	.3357	12.49	.53
GW59	.3420	12.71	.54
B359	.3586	13.33	.57
C304	.3590	13.34	.57
A102	.3795	14.11	.60
A100	.4235	15.74	.67
LSD 5% pt.	.0224	.....	.....
LSD 1% pt.	.0299	.....	.....

From the appearance of the daily oxygen measurements obtained early in the test it was doubted that the differences in oxygen consumption between varieties would be significant with only two replications. An analysis of variance using the variates, varieties, and replications substantiated this doubt. For the second test it was decided to run more replications and fewer varieties. Subsequently, an analysis of variance was made using the variates, replicates, weeks, and varieties, which reduced the error appreciably. Thus, this method of analysis was used for obtaining errors and calculating LSD (least significant difference) for results given in both tables. The results for the second test are given in Table 2.

Table 2.—Cubic feet of oxygen (at V_0) consumed per day by 100 pounds of beets of three varieties stored at 70° F. during the six weeks from December 21 to February 1.

Week	Variety C455	Variety B389	Variety GW201	Weekly Mean
1st	.3912	.4015	.4387	.4105
2nd	.3342	.3297	.3552	.3397
3rd	.3233	.3147	.3398	.3259
4th	.3358	.3217	.3443	.3339
5th	.3695	.3305	.3870	.3623
6th	.3713	.3492	.3932	.3712
Variety Mean	.3542	.3412	.3764	.....

Varieties LSD—5% pt. = .0219, 1% pt. = .0290
Weeks LSD—5% pt. = .0155, 1% pt. = .0205

The first test (Table 1) showed highly significant differences between varieties but no significant differences between the varieties C455, GW201, and B389. Taking these three varieties and studying their rate of respiration in a second test with six replications gave results (Table 2) which show GW201 as poorer in storage quality in comparison with the other two varieties, using oxygen consumption as the criterion. That differences in storage

quality between varieties do exist appears to the writers to be a valid conclusion. However, the relative ranking of varieties with regard to storage, or keeping, quality might well change as further refinements in techniques are made.

Summary

A study of respiration and spoilage rates of different sugar beet varieties, lines, and individuals was initiated in the fall of 1949. By measuring oxygen consumed at daily intervals over an extended period, combined with a rating on the observed soundness of the beets at the end of the period, an estimation in the differential storage quality between genetically different materials was made. Also, techniques for measuring respiration rates and evaluation of storage qualities which might be sufficiently accurate and more applicable to a breeding program were under investigation.

Possibilities for Improving Storage-Rot Resistance of Sugar Beets Through Breeding[1]

JOHN O. GASKILL[2]

Rotting of sugar beets, *Beta vulgaris* L., in storage piles between time of harvest and processing is an extremely important problem in most sugar beet regions in the United States. The seriousness of this problem and factors related to its control have been discussed by various investigators—e.g. Larmer (3)[3], Gaskill (1, 2), and others—and will not be reviewed in this paper.

Experimental work was begun at Fort Collins, Colorado, in the spring of 1948 in order to investigate the possibility of attacking this problem effectively by breeding for storage rot resistance. The work performed thus far includes comparison of uninoculated field-grown roots of various strains for keeping quality and preliminary studies pertaining to resistance of strains and of individual roots as measured by rate of rotting following artificial inoculation. Definite conclusions regarding the effectiveness of the selection techniques used must await the outcome of further work, especially progeny tests, and consequently this paper is presented merely as a progress report.

Comparison of Beet Strains by Means of Uninoculated Roots

Thirty strains of *B. vulgaris*, including sugar beets, garden beets, 1 mangel variety, and several hybrids (sugar- x garden beet and mangel) were grown in 4-row, 29-foot plots in a field near Fort Collins, Colorado, in 1948. Randomized-block design was used, 3 blocks receiving a moderate application of a complete fertilizer and 3 blocks receiving no fertilizer. Data from another experiment indicated that this field was moderately deficient in nitrogen and slightly deficient in available phosphorus. The crop was planted on May 1, handled in the usual manner throughout the season, and harvested September 29-October 1. Seedling disease and certain mechanical difficulties resulted in thin stands in scattered plots, and consequently harvest was limited entirely to competitive beets—i.e., plants having approximately normal competition. One strain was deleted entirely because of poor stand resulting from low germination.

For storage comparisons, two 25-beet samples were dug by hand in each plot, where stand was adequate, and topped as shown in Figure 1, care

[1] Report of a study made under the Research and Marketing Act of 1946. Colorado A & M Agricultural Experiment Station Scientific Journal Series No. 322.

[2] Pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, Fort Collins, Colorado. Acknowledgment is made to the Botany and Plant Pathology Section of the Colorado Agricultural Experiment Station and to the Beet Sugar Development Foundation for facilities used in connection wih these investigations, and to Dr. G. H. Coons of the Division of Sugar Plant Investigations for helpful suggestions in connection with the planning of the experiments.

[3] Numbers in parentheses refer to literature cited.

Figure 1. Interior and exterior views of 4 sugar beet roots after approximately 4½ months' storage at 45° F.: left, 2 roots of strain 5; right, 2 roots of strain 7; attempt made to pick representative roots from comparable samples.

being taken to avoid spade injury and topping-knife hook injury. Where stand was poor, sample size was reduced to a minimum of 10 roots. After being washed and drained, the 2 samples from each plot were placed in shallow wooden boxes and stored in insulated rooms for approximately 3 months at 65° F., and 4½ months at 45° F., respectively. The air in each room was circulated constantly by means of fans, continuous forced ventilation was provided, and relative humidity was maintained at a level high enough to prevent excessive evaporative loss in weight of healthy roots. The latter was accomplished for each room by means of wet Sphagnum moss on floors and on a part of the wall surface and by passing a stream of air over hot water.

At the end of storage the percentage of rot in each sample was determined by separating and weighing the rotted and healthy tissue. There was relatively little overall difference between fertilized and unfertilized replications, in percentage rot, and interaction between strains and fertilizer treatments appeared to be unimportant. Consequently the data from all replications were pooled as shown in Table 1. These averages show highly significant differences between sugar-beet strains, in percentage rot, with significant positive correlation between 65° and 45° results. It is of interest to note the contrast between certain groups of strains—e.g., those descending from the 1833 source (strains 4, 5, and 6) as compared with those derived from 1846 (strains 7, 8, 9, and 10). The exceptionally low rot percentages obtained for the 2 garden beet varieties (strains 26 and 27) are noteworthy and suggest the possibility of using that branch of the species as a source of resistance.

Inoculation Studies

In March, 1949, approximately 400 mother beets[4] of strain 21 which had been stored since fall in the 45° room previously described were inoculated for the purpose of selecting storage-rot-resistant individuals. Inoculum was prepared by chopping and machine blending healthy and rotted tissue from a number of partially rotted sugar beets which had been similarly stored. A small amount of water was added to facilitate blending. An area

[4] Full-sized roots with crowns; suitable for growing seed.

Table 1.—Comparison of keeping qualities of strains of beets stored approximately 3 months at 65° F. and 4½ months at 45° F.; results given as 6-plot averages. Fort Collins, Colorado, 1948-49.

Strain designation used in text	Sugar Plant Invest. seed No.	Description and Source[a]	Final stand per 100′ Number	Wt. of rotted tissue at end of storage 65° F.[b] Percent	45° F. Percent
1	Acc. 5072	U.S. 22/3; curly-top-resistant commercial variety	96	20.1	6.9
2	Acc. 1099	G.W. 59; Great Western Sugar Co. commercial variety	91	13.9	6.0[1]
3	Acc. 1098	U.S. 215 x 216/3; leaf-spot resistant commercial variety	99	15.4	9.1
4	451-0	Improved U.S. 216; inbred; 1833	93	9.2	9.0
5	1-16-0	U.S. 216; inbred; 1833	96	14.2	5.6
6	451047-0	Tetraploid U.S. 216, developed by F. A. Abegg[c] from diploid 1-16-0; 1833	78	5.9[1]	3.6[2]
7	471003-0	U.S. 225; inbred; 1846	80	28.1	11.7[2]
8	4-1005-0	U.S. 215; inbred; 1846	74	33.2[2]	.....
9	461020-0	Improved U.S. 215; inbred; 1846	74	20.5[2]	25.4[2]
10	461015-0	Tetraploid U.S. 215, developed by F. A. Abegg[c] from diploid U.S. 215; 1846	77	23.1[1]	6.8[2]
11	455-0	Unnamed European strain improved by mass-selection	69	11.3[3]	.....
12	0-13-0	Inbred; 10545	83	10.4	2.9[1]
13	471002-0	Inbred; La Royale	94	19.0[1]	6.1
14	1-12-0	Italian strain improved by mass selection; R-581	96	19.7	5.1
15	462-0	Inbred; Old Type	57	.....	.....
16	4-4-0	Inbred; 2140	86	14.0	5.2
17	471001-0	Inbred; Pioneer	84	28.2[1]	4.4[2]
18	461004-0	Inbred; G.W. 49	59	7.0[3]	.....
19	9-290-0	Inbred; 2092	73	13.7[1]	4.9[3]
20	4-1048-0	Inbred; 1846 x 1833	82	35.2	12.2[1]
21	471004-0	U.S. 226 (wide-base synthetic variety)	93	10.9	3.3
22	451057-0	Synthetic variety involving a trace of *B. maritima* ancestry	78	22.6[2]	6.2[3]
23	Acc. 1080	Mammoth Long Red mangel	88	31.0	7.3[1]
24	4-1026-0	Unselected increase of Old Type	76	22.3[1]	10.1[2]
25[d]	4-1839-02	F_1; Old Type x Mam. Long Red Mangel	93	19.5	5.2
26	Acc. 1078	Improved Blood garden beet	79	6.4	1.7[2]
27	Acc. 1102	Crosby's Egyptian garden beet	83	9.2[2]	3.3[1]
28	451064-0	Mass increase of the cross, U.S. 216 x (sugar x garden beet)	92	12.5	4.1
29	Acc. 1103	G. W. Deming[e] No. 1945-309; produced from a cross of U.S. 215 x garden beet by 3 generations of mass selection for high root weight and high sucrose percentage	98	22.2[1]	4.4
30	Acc. 1104	G. W. Deming[e] No. 1945-307; 3 generations of low-weight, low-sucrose selection from above cross	82	7.0[1]	2.6[2]
General mean				17.42	6.57
L. S. D. (5-percent point)				11.3	6.4

Correlation of results for two temperatures (strain 8, 11, 15, and 18 omitted):

r	0.469
t	2.602
P	<0.02

[a] Strains are of sugar beet origin except as otherwise indicated. The term "inbred" indicates at least one generation of selfing.

[b] Roots went into storage during the first week of October, approximately. Rot weighings for the 65° room were made for two replications on December 9, 1948, and for the other four replications during the period, January 3-6, 1949.

[c] Formerly Geneticist, Division of Sugar Plant Investigations.

[d] Only known F_1 roots, identified by pink or red root color, were used for storage comparisons.

[e] Agronomist, Division of Sugar Plant Investigations.

[1 2 3] Because of missing sample or samples (generally due to inadequate stand), one, two, or three "missing-plot" values, respectively, were estimated for the indicated strain and storage temperature. Where more than three plot values were missing for a given strain and temperature, no rot percentage is shown.

of about 2 to 3 square inches on one side of each root was scraped with an ordinary vegetable grater, approximately 1 teaspoonful of inoculum was placed on the injured surface, and storage was continued under the same conditions. Five weeks after inoculation the roots were found to differ greatly in depth of rotted tissue beneath the inoculated area (Figure 2). One hundred nine of the more resistant-appearing individuals were transplanted in the field in a single group and allowed to interpollinate. Progenies of surviving plants are to be evaluated for storage-rot resistance in future tests.

A preliminary inoculation experiment was conducted in December and

Figure 2. Four mother beet roots of strain 21 after wound inoculation with composite rot inoculum and incubation for 5 weeks at 45° F. Note variation in depth of rotted tissue (top of freshly cut section outlined with chalk).

January, 1949-50, partly for the purpose of comparing two contrasting strains listed in Table 1 and partly to study methods of evaluating the resistance of individual roots by pure-culture technique. Twenty-two selected mother beets of each strain which had been taken from two comparable field plots in October, 1949, were cut in half longitudinally. One-half of each root was saved for possible seed production. Crown and tail portions of the other half were removed and the remaining piece was inoculated with blended potato-dextrose agar inoculum of a virulent culture of *Phoma betae* Frank which had been isolated from a sugar beet storage-rot specimen.

Two methods of inoculation were used for each root piece, as follows: (1) A portion of the exterior of the root was peeled with an ordinary vegetable peeler, removing one layer about 1 mm. in thickness, and one drop of the semi-fluid inoculum was applied to the injured surface in each of 2 places; and (2) a round plug about ½ inch long was removed from the outer part of the root, inoculum was inserted in the bottom of the hole.

Table 2.—Rate of rotting in sugar beet roots inoculated with *Phoma betae* and held at 45° F. for 35 days. Fort Collins, Colorado, 1949-50.

Strain[a] No.	Root No.	Depth of discolored tissue: Peeled-surface[b] inoculation	Depth of discolored tissue: Plug[c] inoculation	Average
		Mm.	Mm.	Mm.
7	1	6.0	6.0	6.00
	2	4.3	4.0	4.15
	3	6.0	7.5	6.75
	4	2.5	5.0	3.75
	5	8.3	8.5	8.40
	6	3.0	5.5	4.25
	7	6.0	7.0	6.50
	8	3.8	7.5	5.65
	9	10.5	13.0	11.75
	10	6.3	10.5	8.40
	11	6.0	8.0	7.00
	12	3.5	3.0	3.25
	13	5.5	7.5	6.50
	14	2.3	5.0	3.65
	15	6.5	4.5	5.50
	16	3.5	4.5	4.00
	17	4.3	7.5	5.90
	18	6.3	7.5	6.90
	19	6.3	6.5	6.40
	20	1.0	6.0	3.50
	21	7.0	8.0	7.50
	22	4.3	7.0	5.65
	Aver.	5.15	6.80	5.97
21	1	2.8	4.5	3.65
	2	2.3	4.0	3.15
	3	3.5	3.5	3.50
	4	2.3	4.5	3.40
	5	7.0	7.0	7.00
	6	2.3	5.0	3.65
	7	2.5	3.0	2.75
	8	1.5	14.0	7.75
	9	6.5	6.0	6.25
	10	0.5	0.5	2.50
	11	4.0	5.0	4.50
	12	2.0	5.0	3.50
	13	2.0	2.5	2.25
	14	4.5	3.0	3.75
	15	4.8	10.0	7.40
	16	1.8	5.5	3.65
	17	6.5	9.0	7.75
	18	9.5	9.0	9.25
	19	8.0	10.0	9.00
	20	3.3	4.0	3.65
	21	8.5	8.5	8.50
	22	1.8	3.0	2.40
	Aver.	4.00	5.93	4.96

Correlation of surface and plug inoculation results:	
r	0.574
t	4.543
P	<0.01
L. S. D. (5-percent point) for individual roots	3.33
L. S. D. (5-percent point) for means of strains	0.71

[a] Strains described in Table 1.
[b] Each value given is an average obtained from two inoculations.
[c] Each value is an average of two measurements made in opposite directions, longitudinally, from one inoculation.

and the plug was replaced and sealed with paraffin. Care was taken to use uniform quantities of inoculum for each type of inoculation. The inoculated pieces were suspended over a free water surface in loosely covered galvanized-iron containers in which temperature was 45° F. and relative humidity practically 100 percent. After 35 days, the depth of rotted tissue was measured, radial penetration being recorded for the peeled-surface inoculations and longitudinal penetration for the plug inoculations.

The results of this experiment are summarizd in Table 2. Longitudinal penetration, from plug inoculations, was definitely faster on the whole than penetration from peeled-surface inoculations. However, since positive correlation between the two sets of measurements was highly significant, the average column (Table 2) may be used for comparison of strains and of individual roots. The average rate of rotting for the roots of strain 21 was significantly lower than that obtained for strain 7, thus agreeing with the results obtained from uninoculated roots in an earlier experiment (Table 1). The occurrence of highly significant differences between roots of each strain tends to substantiate the results of another experiment, previously discussed and illustrated in figure 2. Although conclusions as to the extent to which such individual root differences are inherited must await the results of progeny tests, these results, together with the strain differences shown in both tables, seem to justify the tentative conclusion that improvement in keeping quality of sugar beets can be expected from a program of selection and breeding for storage-rot resistance.

Summary

Keeping qualities of samples of uninoculated roots of 29 strains of beets, including one mangel and two varieties of garden beets, were compared in a replicated experiment under 65° F. and 45° F. storage conditions. At the end of storage, certain sugar beet strains differed very significantly in percentage of rotted tissue, and both garden beet varieties were quite low in that respect. Relative strain performance at the two temperatures showed significant, positive correlation.

Two of the 29 strains which differed considerably in percentage rot were compared in a later experiment by means of roots inoculated with *Phoma betae* and held at 45° F. for 5 weeks. The two strains differed significantly in average rate of rotting, the results agreeing with those obtained from the earlier experiment, and a number of individual differences between roots, within each strain, were highly significant. Approximately 400 mother beets of the more resistant of these two strains were inoculated with composite storage-rot inoculum and compared after incubation for five weeks at 45° F. The roots differed greatly in rate of rotting, and the more resistant ones were brought to seed for the purpose of progeny testing.

The results reported seem to justify the tentative conclusion that breeding for storage-rot resistance in sugar beets should be advantageous.

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Studies on the Respiration of Sugar Beets as Affected by Bruising, by Mechanical Harvesting, Severing Into Top and Bottom Halves, Chemical Treatment, Nutrition and Variety

MYRON STOUT[1] AND C. H. SMITH[2]

Introduction

Loss of sugar and quality from sugar beets during storage results from a combination of respiration and spoilage of the roots. Since two separate factors are involved it is necessary to study both in an attempt to improve storage conditions. If both factors can be studied at the same time on the same beets, kept under the same constant environmental conditions, the data secured should prove most valuable. The equipment and technique to be described was developed by C. A. Fort and the senior author to meet these requirements. The equipment and technique works very well in studies of various factors such as topping level, effect of partial drying before storage, various storage atmosphere compositions and chemical treatments of the roots. The method, however, has certain limitations for breeding and selection work. It is designed primarily for fairly large samples of beets (88 pounds or more) and it requires considerable time and space to get complete data on a large number of samples as needed in selection and breeding work. For this type of program it should be used for studies of progress made in breeding varieties and supplemented by some form of the Warburg technique for respiration and mycological method for resistance to organisms causing spoilage.

Equipment and Methods

The respiration chambers shown in Figure 1 are 55-gallon steel drums fitted with removable tops, gaskets and compression clamps. They are fitted with perforated metal false bottoms about 1 to ½ inches high and a series of about 20 finely perforated metal trays mounted on a small pipe extending from the bottom to near the top of the drum. Discarded centrifugal basket lining was used for making the trays. About six pounds of finely pulverized hydrated lime on the metal trays absorbs the carbon dioxide and some of the respiratory moisture from the beets which are piled around the column of trays. Two 3/16-inch copper tubes are sealed into the top of the drum. One is connected by rubber tubing to a 5-gallon bottle filled with oxygen and mounted on top of the drum. The other copper tube is used for with-

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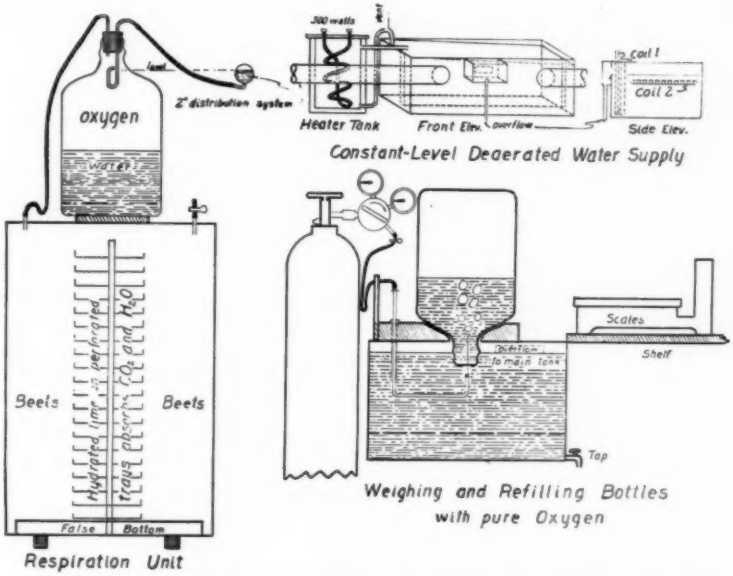

Figure 1. Equipment for respiration studies at constant-atmosphere composition.

drawing gas samples for analysis and for adjusting the oxygen concentration inside the drum. Each 5-gallon bottle is fitted with a two-hole rubber stopper. One glass tube for connecting to the drum should extend about two inches above the stopper (to prevent siphoning of water into the drum in the event that all of the oxygen in the bottle is used up). The other glass tube through the stopper is bent into a gooseneck about 1½ to 2 inches long, but narrow so that it can be inserted easily into the bottle. It should also extend through the stopper about 2 inches to enable easy adjustment with the constant-level, deaerated water supply without raising or lowering the drum.

A surplus of water is deaerated by heating to about 140° to 160° F. and allowing it to flow in a thin film across a metal tray before entering the constant-level tank. Two copper coils in the constant-level tank serve the dual purpose of cooling the heated water and warming the feed water before it is finally heated in a small tank equipped with a 500-watt immersion coil heater. Cold water flows into a sight feed tube, then through the primary copper coil in the front compartment of the constant-level tank. This part is insulated from the main body of the tank by a double partition extending to near the bottom of the tank. The water then flows through the secondary coil which is supported in a horizontal position about ½ inch below the surface of the water in the larger compartment of the tank. It then flows to the bottom of the insulated immersion heater tank, is heated to 140° F. or more and flows across the metal tray and into the main body

of the constant-level tank. Partially cooled water flows under the double partition and into the front compartment where it is cooled to near room temperature for use in the distribution system or to the waste overflow. Sediment or floating solids are removed by the partition. The overflow is conducted to the tank for filling the bottles with water and then oxygen by water displacement.

With the convenient equipment for refilling the bottles with oxygen shown in figure 1, one man can weigh 16 bottles and refill them with oxygen in about 40 minutes.

Since temperature control is very important the drums are supported about two inches from the floor and air is circulated throughout the room by a fan. Air temperature in the room is kept constant by the addition of a small amount of heat from a 1,000-watt fan-equipped heater located near a good-grade thermostat equipped with a solenoid switch. The air from the heater is directed toward the thermostat so that the temperature of the room never exceeds the thermostat setting.

Periods of declining barometric pressure reduce the apparent respiration rate by causing expansion of the gas in the drum and bottle. This error can be corrected by calculating the expansion due to the change in pressure, but the practice at Salt Lake City has been to average daily values for periods long enough to compensate for changes in barometric pressure.

The use of 40 kg. of beets per drum was chosen because this is about the safe limit for some samples of beets to be supplied with oxygen from a 5-gallon bottle for 24 hours at 68°-70° F. and 655 mm. barometric pressure. By refilling the bottles twice daily or by lowering the temperature larger samples can be used.

Sampling the beets for respiration and chemical analysis is probably the most difficult problem. Each lot to be tested is washed, uniformly topped and the taproot trimmed off to avoid breakage in handling. Samples are then selected to give uniform number, weight and size distribution of beets. The beets are then sealed in the drums, connected to the oxygen and de-aerated water supply and the gooseneck adjusted about ¼ inch above the water-supply level when the sampling outlet to the drum is open. A small amount of air is withdrawn to start the flow of water into the bottle and the sampling outlet closed. Any leakage to the system will cause the dropping of water into the bottle to stop. After a period of 12 to 20 hours of testing for leaks and allowing the sugar beet roots to reach thermal equilibrium with the room, the sampling outlet is again opened, the gooseneck lowered so that water barely drips into the bottle, the sampling outlet closed and the bottle refilled with oxygen. The water is weighed and the bottles refilled at the same time each day thereafter during the test.

Samples of the gas in the drum are withdrawn periodically for analysis and a correction for the volume of gas withdrawn is applied to the tare weight of the bottle. The oxygen concentration in the drums was usually

held at 20 to 22 percent during the tests reported here. The CO^2 was less than 0.1 percent. A piece of 1/16-inch diameter rubber tubing is convenient for withdrawing samples for analysis so that the Orsatt apparatus need not be moved.

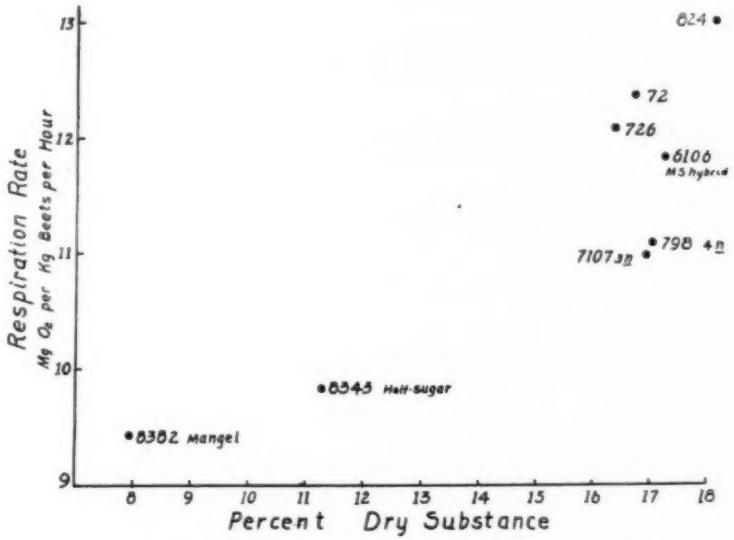

Figure 2. Relation of respiration rate of various varieties of beets to percent dry substance.

Experimental Results

Eight varieties or treatments of sugar beets were studied in 1948. Respiration tests were run in duplicate, with two analytical samples of twenty beets each per drum. By analyzing separately the top and bottom halves of some of the samples of the sugar beet variety S. L. 710 from the Harman farm, both before and after the respiration test, it was possible to obtain data on losses caused by severing the beets before storage as well as the differential losses from the top and bottom halves of beets which were stored intact and then the respective portions analyzed. The effect of three rates of application of "Barsprout," a commercial product used to prevent sprouting of potatoes, was studied. Barsprout contains 2.2% methyl ester of naphthaleneacetic acid in a fine, inert powder. It is dusted on the potatoes as they are stored.

Comparisons were made between beets which were harvested carefully by hand and others harvested by a machine equipped with a Reinks screen. Other comparisons were made between two different varieties grown on the same field and the same variety grown on two different fields.

Table 1.—Effect of variety, field, harvesting method and chemical treatment on respiration, chemical change and losses during respiration test at 68° to 70° F. for 45 days. (Respiration rates are average values of two tests for 10 days for each period.)

Variety, source and treatment	Respiration rate mg. 0_2 per kg. of beets per hour 10-day period No.				Analytical losses (original minus final analysis)				Sugar losses per ton per day		
	1	2	3	4[1]	Dir. pol. (Sugar)	Dry sub.	Purity coef.	Invert (incr.)	Resp. (2nd period)	Invert or spoilage	By anal. dir. pol.
	Mg.	Mg.	Mg.	Mg.	%	%	%	%	Lbs.	Lbs.	Lbs.
S. L. 710 (Harman farm)											
Carefully dug	13.0	10.8	10.4	10.0	0.98	0.73	2.05	0.20	0.46	0.09	0.44
Machine dug	13.1	10.2	9.7	9.6	1.26	0.86	2.95	0.21	0.44	0.09	0.56
Top and bottom halves severed	17.6	13.9	15.4	16.8	2.13	1.71	3.96	0.52	0.59	0.23	0.93
Top halves intact					1.36	1.04	2.71	0.21		0.09	0.60
Top halves severed					2.18	1.82	3.85	0.45		0.20	0.97
Bottom halves intact					0.94	0.58	2.32	0.20		0.09	0.42
Bottom halves severed					2.09	1.59	3.94	0.59		0.26	0.93
S. L. 710 (Hill farm)											
Carefully dug[2]	11.2	9.2	9.2	10.0	1.58	0.95	4.78	0.27	0.39	0.12	0.70
1.56 lbs. Barsprout[2]	16.8	12.6	13.7	16.4	2.02	1.32	5.70	0.36	0.54	0.16	0.90
3.12 lbs. Barsprout[2]	18.8	14.9	17.4	21.7	2.76	1.62	8.99	0.65	0.64	0.29	1.23
6.24 lbs. Barsprout[2]	18.9	16.7	17.0	18.4	2.08	1.29	6.16	0.41	0.71	0.18	0.92
S. L. 79 (Hill farm)											
Carefully dug	13.8	13.1	16.0	21.6	1.80	1.24	4.62	0.37	0.56	0.16	0.80
Average all treatments:	15.4	12.7	13.6	15.6							

[1] 15-day period
[2] Pounds Barsprout per ton of beets

Average respiration rates, grouped into three ten-day periods and one 15-day period, are shown in Table 1. The rather rapid decline in respiration rate after the first 10-day period is observed on nearly all samples harvested

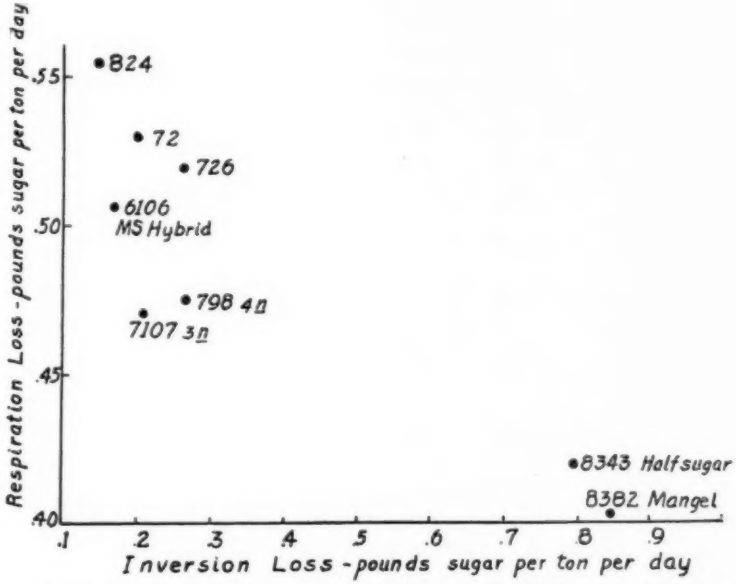

Figure 3. Relation of losses of sugar from several varieties of beets due to respiration and inversion or spoilage.

in the fall and is correlated with reversal of thermal induction when thermally induced sugar beets are stored at a warm temperature. Later increases in respiration rate are usually correlated with spoilage of the beets and may be due partially to respiration of fungi on the roots. The second 10-day period probably represents the normal, non-spoilage respiration rates of the beets under study.

The differences in chemical analysis of the beets before and after the 45-day period at 68° to 70° F. and losses of sugar in pounds per ton of beets per day as calculated from normal respiration, decreased direct polarization and increased invert sugars are also shown in Table 1. It is evident from the data that the normal bruising and abrasions the beets received in machine harvesting caused no increased loss due to respiration or inversion over beets which were harvested carefully by hand. The lower loss, based on direct polarization, of the carefully harvested beets might be questioned because it is lower than the normal respiration loss. This is theoretically improbable. Severing into top and bottom halves, however, greatly increased respiration

Table 2.—Respiration rates, chemical change and losses of different varieties of beets during respiration test at 68° to 70° F. for 48 days. (Respiration rates are average values of two tests for 10 days for each period.)

Variety S. L. No.	Respiration rate mg. 0_2 per kg. of beets per hour 10-day period No. 1	2	3	4	5[1]	Analytical losses (original minus final analysis) Dir. pol. (sugar)	Dry sub.	Purity coef.	Invert (incr.)	Sugar losses per ton per day Resp. (2nd period)	Invert or spoilage	By anal. dir. pol.
	Mg.	Mg.	Mg.	Mg.	Mg.	%	%	%	%	Lbs.	Lbs.	Lbs.
798	12.9	11.1	11.0	11.1	10.1	2.34	2.06	3.78	0.64	0.48	0.27	0.98
824	14.8	13.0	13.3	13.0	11.5	2.06	1.84	2.80	0.35	0.56	0.14	0.86
7107	12.5	11.0	11.4	11.3	10.2	1.57	1.25	3.18	0.50	0.47	0.21	0.65
72	13.6	12.4	12.9	13.1	12.4	2.13	1.59	5.00	0.48	0.53	0.20	0.89
6106	13.7	11.9	11.5	11.6	10.3	1.01	1.07	0.49	0.40	0.51	0.17	0.42
729	14.0	12.2	11.9	12.3	11.0	2.31	2.00	4.13	0.62	0.52	0.26	0.96
8382	9.5	9.4	11.0	13.3	14.6	3.43	1.45	38.80	2.03	0.40	0.85	1.43
8343	10.2	9.8	11.5	13.9	15.0	3.63	1.66	24.13	1.91	0.42	0.80	1.51

[1] 7-day period

and inversion losses as well as loss in polarization. The top halves of beets stored intact showed no difference from the bottom halves in spoliage but sugar loss was greater from the top halves. This was no doubt due to a greater respiration rate of the top halves as shown in previous studies. Apparently translocation of sugar from bottom to top did not compensate for the greater respiratory loss of sugar from the top. Loss of sugar from the top halves of severed beets was slightly greater than that from the bottom halves but spoilage was greater in the bottom halves. This small difference again suggests greater respiration as being the cause.

Variety S. L. 710 from the Hill farm sustained a lower respiration loss but greater spoilage than S. L. 710 from the Harman farm. The loss in purity of S. L. 710 from the Hill farm was also more than twice that of the same variety grown on the Harman farm. Losses were greater in variety S. L. 79 from both respiration and spoilage than S. L. 710.

Dusting beets with Barsprout at either one-half, normal or twice the amounts recommended for potatoes greatly increased the respiration, spoilage and loss of sugar from the beets. Barsprout cannot be recommended for the storage of sugar beets. Research at the Boyce Thompson Institute for Plant Research has shown that methyl ester of naphthaleneacetic acid is effective in preventing the accumulation of objectionable sugars in potatoes stored at cool temperature. It seems probable that increased respiration of the potatoes utilizes the sugars as fast as they are formed and thus prevents accumulation. However, the writers know of no reports on the effect of this chemical on the respiration of potatoes.

Effect of Added Commercial Fertilizer on the Respiration and Spoilage of a Single Variety of Sugar Beet

Applications of commercial fertilizers were made to 4-row strips of beets on the Carlisle farm, near Salt Lake City, May 25, 1949. The field had been planted April 14 with variety U. S. 22/3. The plot was selected because it was a light sandy loam soil, had been in beets the previous year, had not been fertilized following the beet crop and had shown no evidence of nematode infestation. Eight treatments were included in the test. The fertilizer was added to both sides of each of the two center rows and these were used for the yield, chemical analysis and respiration studies. There was little evidence of response to the added fertilizers during the summer or at harvest September 23, 1949.

The yields and chemical analyses indicated no evidence of nutritional deficiency but did indicate some small reductions in sugar and purity of the beets which received large applications of nitrogen fertilizer. The addition of a mixture of minor elements apparently increased the yield of beets and reduced sugar and purity slightly. The respiration data indicated only small differences between treatments. The addition of minor elements to plots which received large amounts of phosphorus and nitrogen apparently increased respiration slightly. Losses expressed in terms of pounds of sugar per ton per day as calculated from respiration rates, inversion and direct polarization, also indicated slightly greater losses were sustained by the beets fertilized with minor elements. Lower loss from inversion or spoilage of the beets which received no added fertilizer and greater losses from those which received minor elements were indicated by the data.

It seems reasonable to expect that, in the absence of nutritional deficiencies, normal rates of application of commercial fertilizezrs will affect storage only slightly if at all.

Large beets respire more slowly than an equal weight of smaller beets. In selecting comparable sized beets for respiration studies one probably unconsciously eliminates nutritional differences by selecting more closely spaced beets from highly fertilized plots and widely spaced beets from low-fertility plots. Space allotments, therefore, may greatly alter nutritional differences which are expressed in pounds of nutrients per acre. Nutritional deficiencies or greatly unbalanced nutrition might be expected to affect storage. It is almost certain that high yields, if due to larger beets, would result in lower respiration losses.

Respiration and Spoilage of Widely Different Varieties of Beets

Beets of widely different genetic constitution and growth habits were grown on the Harman farm near Riverton, Utah, in 1949. Some of the more pertinent information regarding the genetic character of these varieties is as follows:

S. L. 798—4*n* U. S. 22/2
S. L. 824—High-sugar selection U. S. 22/3
S. L. 7107—3*n* male-sterile hybrid
S. L. 72—Curly-top selection U. S. 22/3
S. L. 6106—U. S. 41 male sterile x CT9 inbred
S. L. 726—Low-sugar selection U. S. 22/3
S. L. 8382—Barres mangel
S. L. 8343—Half-sugar from Holland

The Barres mangel is a globe-shaped, orange-colored beet which grows high above the soil level. The half-sugar beet from Holland produces a high tonnage of green-colored, elongated roots which also grow high above the level of the soil. Because of their elongated shape the half-sugar beet has a much larger surface per unit of volume than the Barres mangel.

The beets were sampled and sealed in the respiration chambers November 1, 1949. The respiration and spoilage test was discontinued December 19 after a storage period of 48 days at 68° to 70° F. Respiration based on average rates for 10-day periods is shown in Table 2. Varieties S. L. 824, S. L. 72 and S. L. 726 respired more rapidly than the other varieties of sugar beets. The Barres mangel and half-sugar respired much more slowly during the early part of the test but increased considerably during later periods, indicating greater spoilage of these two varieties. Although the mangel and half-sugar showed little evidence of spoilage when the test was discontinued they showed large losses in purity and increases in invert sugar when analyzed. The analysis of the various samples before and after storage show that the mangels lost more than one-half their original purity value during storage.

The freshly harvested Barres mangels contained nearly eight times as much invert sugar as did the sugar beets. The freshly harvested half-sugar beets were more nearly comparable to sugar beets in invert sugar percentage but after storage they were more nearly comparable to the mangels.

Losses in pounds of sugar per ton of beets per day of storage are also

shown in Table 2. Interrelationships of some of the data in Table 2 are shown graphically more clearly in Figures 2 and 3.

Figure 2 shows a fairly good positive correlation between percentage dry substance and respiration rate with the exception of varieties S. L. 7107, S. L. 798 and S. L. 6106. The two polyploid varieties have considerably lower respiration rates in relation to dry substance than the normal diploids. The male-sterile hybrid S. L. 6106 is intermediate in respiration rate in relation to dry substance.

The relationship between inversion or spoilage and respiration losses shown in Figure 3 indicates a fairly close negative correlation between these two factors responsible for the overall storage losses. Here again, the polyploids show superiority with the male-sterile hybrid in an intermediate position. The data also show a fairly close negative correlation between percentage sugar and spoilage or inversion loss. These interrelationships of the data presented on the varieties studied indicate good possibilities of breeding for improved storage, especially in relation to polyploid varieties of beets.

Summary

A method for measuring the respiration rate and spoilage of fairly large samples of sugar beets (88 pounds) in an atmosphere of constant composition and temperature is described.

The bruising which the sugar beet roots received in harvesting by means of a mechanical harvester equipped with Reinks screens did not cause appreciable increase in respiration rate or spoilage.

Beets severed into top and bottom halves before storage respired more and spoiled more rapidly than beets stored intact. Greater losses from respiration were evident in the top halves but greater losses from spoilage occurred in the bottom halves. Beets stored intact showed greater sugar loss from the top half than from the bottom half, indicating that translocation of sugar does not compensate for the greater drain of sugar from the top halves.

Barsprout, containing methyl ester of naphthaleneacetic acid, greatly increased the respiration rate and growth of rootlets on sugar beets. It cannot be recommended for the storage of sugar beets.

The data to date show no advantage of highly fertilized over normally fertilized beets. In one test, where there were evidently no deficiencies in the check beets, the addition of nitrogen and phosphorus and a mixture of minor elements produced no improvement in storage ability. The effect of added fertility on samples of uniform sized beets is discussed.

Of eight varieties studied, including a mangel and a half-sugar beet, in relation to respiration, there seems to be a rough positive correlation between sugar percentage and respiration rate. However, one male-sterile hybrid (S. L. 6106), a triploid (S. L. 7106) and a tetraploid (S. L. 798) were lower in respiration rate in relation to sugar percentage than the other three varieties of sugar beets (S. L. 726, S. L. 72 and S. L. 824). This may offer promise of breeding for lower respiring commercial varieties.

Progress Report on the Effects of Nutrition, Bruising, and Washing Upon Rotting of Stored Sugar Beets[1]

JOHN O. GASKILL[2]

Rotting of stored sugar beets, *Beta vulgaris* L., is a problem of major importance in the sugar beet industry in the United States. Rotting is caused by microorganisms which are greatly influenced by various conditions of storage as well as by the nature and condition of the beet roots stored. The role of certain of these factors, in relation to severity of rot losses, has been discussed by Tompkins and Nuckols (5)[3], Larmer (4), Gaskill (1, 2, 3), and by other investigators.

This paper, based on one year's results, is presented merely as a progress report on certain studies initiated at Fort Collins, Colorado, in 1948. Samples of topped sugar beet roots were stored in two insulated rooms under controlled conditions described by the author in another article (2). At the end of storage, the proportion of rot in each sample was determined by separating and weighing the rotted and healthy tissue.

Nutrition

In the spring of 1948 a field near Fort Collins, Colorado, which had produced a low yield of sugar beets in 1947 and which was thought to be relatively low in general fertility was chosen for use in studying effects of nutrition upon keeping quality. The inorganic fertilizers, ammonium nitrate, treble superphosphate, and muriate of potash, were applied on the surface before plowing in April, with rates and combinations as outlined in Table 1. The 18 fertilizer treatments were placed in the field in equalized random blocks, with 3 replications, and subdivided by strips of 3 varieties in random arrangement. Individual plots were 4 rows x 40 feet; rows 20 inches apart. Border effects of fertilizer treatments were eliminated by suitable buffer strips and harvest alleys.

Harvest yields and sucrose data were obtained as a means of evaluating the deficiencies of the 3 nutrients under study. Root yield was determined for each plot from the washed weight of all roots in 36 feet of row, and sucrose percentage was obtained from one 20-beet sample per plot. Response to potash fertilizer was negligible. Phosphate fertilizer did not affect sucrose percentage significantly, but the average acre yield of roots for the heaviest application was 1.24 tons above that of the unphosphated plots—a

[1] Report of a study made under the Research and Marketing Act of 1946. Colorado A & M Agricultural Experiment Station Scientific Journal Series No. 320a.

[2] Pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, Fort Collins, Colorado. Acknowledgment is made to the Botany and Plant Pathology Section of the Colorado A & M Agricultural Experiment Station and to the Beet Sugar Development Foundation for facilities used in connection with these investigations, and to Dr. G. H. Coons of the Division of Sugar Plant Investigations for helpful suggestions in connection with the planning of the experiments.

[3] Numbers in parentheses refer to literature cited.

Table 1.—Fertilizer applications in replicated field plots, Fort Collins, Colorado, 1948.

Pounds[1] K_2O per Acre	Pounds[1] P_2O_5 per Acre	Pounds N applied per acre and treatment No.[1]		
		0	50	150
0	0	1	2	3
	100	4	5	6
	300	7	8	9
50	0	10	11	12
	100	13	14	15
	300	16	17	18

[1] Fertilizers used:
N—Ammonium nitrate.
P_2O_5—Treble superphosphate.
K_2O—Muriate of potash.

significant difference. Response to nitrogen was much more pronounced and highly significant, with average root yields of 9.07, 10.80, and 12.44 tons per acre and average sucrose percentages of 16.59, 16.55, and 15.92, respectively, for 0, 50, and 150-pound applications of nitrogen per acre.

One sample of 20 washed roots from each of the 162 field plots was stored at 65° F. for approximately 3 months, and a duplicate set of samples was held at 45° F. for about 4½ months. Summarized rot percentages at the end of storage are shown in Tables 2 and 3. Since interactions between varieties and fertilizer treatments were not significant, the data for the 3 varieties were pooled. Interactions between nitrogen, phosphorus and potassium were not computed and were disregarded. From the summarized data it appears that none of the 3 nutrient elements influenced materially development of storage rot, except for nitrogen effects under 45° storage. In that room, the average percentage of rot for the 150-pound nitrogen application was less than half the percentage obtained for plots receiving no nitrogen—a highly significant difference. Percentage rot for the 50-pound rate was intermediate and was significantly below that obtained for the zero application.

The beneficial effect of nitrogen upon keeping quality in this experiment, under 45° conditions, is in agreement with results reported by Larmer (4) for roots taken from fertilized and unfertilized plots in a field which he classed as extremely low in fertility. Failure of phosphate and potash fertilization to improve keeping quality need not be considered as contradictory of Larmer's results since those fertilizers produced relatively little root-yield response in the Fort Collins field.

Bruising and Washing

Mechanical injury opens the way for invasion of sugar beet roots by certain kinds of microorganisms, classed as wound parasites, which do not readily penetrate the unbroken periderm. In the process of harvesting, hauling, and piling of sugar beets a certain amount of bruising and gouging is inevitable, and with certain types of mechanical harvesters there is a tendency toward a greater amount of injury than occurs with moderately careful hand topping.

Table 2.—Effects of field fertilization upon development of rot in sugar beet roots during approximately 3 months' storage at 65° F.; results shown as 9-plot averages for each of 18 fertilizer treatments. Fort Collins, Colorado, 1948-49.

K_2O per acre	P_2O_5 per acre	Pounds N per acre and weight of rotted tissue			Average wt. of rotted tissue		Average for P_2O_5	
		0	50	150			P_2O_5 per acre	Wt. of rotted tissue
Lbs.	Lbs.	Percent	Percent	Percent	Percent	Percent	Lbs.	Percent
0	0	29.2	32.2	36.4	32.6)			
	100	31.3	35.8	28.6	31.2)	31.1		
	300	28.5	40.2	19.9	29.5)		0	32.6
							100	32.3
							300	32.5
50	0	36.8	26.3	34.5	32.5)			
	100	28.4	40.5	31.4	33.4)	33.8		
	300	35.5	36.3	34.3	35.4)			
Average		31.6	34.9	30.9				
L. S. D.[1]			5.6			4.6		5.6

[1] Least significant difference (5-percent point) applicable to general averages.

In the fall of 1948 an experiment was designed for the purpose of studying the effects of bruising and, in addition, to furnish information regarding the influence of washing upon keeping quality. The latter factor was included partly because of possible commercial applicability and partly because washed roots were being used in various other storage-rot experiments at the Fort Collins station. Twenty-four comparable 20-beet samples of a commercial variety were divided into 4 lots of 6 samples each which were treated as follows:

(1) Washed, dried, uninjured.
(2) Washed, dried, bruised.
(3) Unwashed, uninjured (approximately 1.7 percent adhering soil).
(4) Unwashed, bruised (approximately 1.3 percent adhering soil after bruising).

Table 3.—Effects of field fertilization upon rotting of sugar beets during approximately 4½ months' storage at 45° F.; results given as 9-plot averages for each of 18 fertilizer treatments. Fort Collins, Colorado, 1948-49.

K_2O per acre	P_2O_5 per acre	Pounds N per acre and weight of rotted tissue			Average wt. of rotted tissue		Average for P_2O_5	
		0	50	150			P_2O_5 per acre	Wt. of rotted tissue
Lbs.	Lbs.	Percent	Percent	Percent	Percent	Percent	Lbs.	Percent
0	0	6.8	7.1	4.0	6.0)			
	100	9.6	5.7	8.3	7.9)	7.0		
	300	8.4	11.4	1.9	7.2)		0	6.6
							100	7.6
							300	6.9
50	0	13.5	3.1	4.9	7.2)			
	100	10.0	8.3	3.4	7.2)	7.0		
	300	10.8	5.6	3.0	6.5)			
Average		9.9	6.9	4.3				
L. S. D.[1]			2.7			2.2		2.7

[1] Least significant difference (5-percent point) applicable to general averages.

The bruising treatment consisted of allowing the beets to tumble 3 times down a board slide 8 feet long, set at a 45° angle from the vertical, and having a ¾-inch wood cleat across the upper surface about half way down and another near the bottom. The roots were caught in a box about 1 foot deep set beneath the lower end of the slide. Aside from the breaking of the tips of some tap roots, injuries produced were of 2 kinds, namely:

Figure 1. Effects of bruising upon keeping quality of washed sugar beet roots. Top—beet samples after storage for 78 days at 65° F.: A, sound; B, bruised. Bottom—4 roots after 119 days' storage at 45° F.: C, D, and E were bruised, arrows indicating severely injured areas, some of which apparently served as openings for initial fungous invasion; F, not bruised.

(1) light scuffing of small areas and (2) deeper bruises or gouged areas, principally those caused by beets striking the cleats on the slide. After treatment each of the 4 groups of samples was divided between the 2 storage rooms.

After 82 days' storage at 65° and 125 days at 45°, the percentage rot in each sample was determined in the usual way, adhering soil disregarded. The results (Table 4) indicate relatively little influence of washing upon percentage rot and negligible interaction between washing and bruising.

Table 4.—Storage rot of sugar beets as affected by bruising and washing; basic data presented as averages of three 20-beet samples. Fort Collins, Colorado, 1948-49.

Treatment	Weight of rotted tissue at end of storage				
	Washed	Dirty	Average	Difference	L. S. D.[1]
	Percent	Percent	Percent	Percent	Percent
		65° F. storage, 82 days			
Bruised	26.1	32.9	29.5)	16.9	12.8
Sound	13.7	11.5	12.6)		
Average	19.9	22.2			
Difference	2.3				
L. S. D.[1]	12.8				
		45° F. storage, 125 days			
Bruised	5.3	6.3	5.8)	1.9	3.2
Sound	2.9	4.9	3.9)		
Average	4.1	5.6			
Difference	1.5				
L. S. D.[1]	3.2				

[1] Least significant difference (5-percent point) applicable only to differences shown—i.e., differences between means of 6 samples. Interaction between washing and bruising treatments was negligible.

Rotting was more severe among the bruised roots at both storage temperatures, the difference being significant in the warmer room. As illustrated in Figure 1, there was a tendency for severely bruised or gouged areas to serve as pathways for fungous invasion, whereas mild bruising or scuffing seemed to have little effect.

Summary

Samples of topped sugar beets were stored at approximately 65° F. and 45° F. for about 3 months and 4 to 4½ months, respectively, and the percentage of rot in each sample was determined at the end of storage by separating and weighing the rotted and healthy tissue.

Beet roots grown in replicated nitrogen-fertilized plots in a field moderately deficient in nitrogen kept significantly better in 45° storage than roots from comparable plots receiving no nitrogen. At 65° there were no significant differences attributable to nitrogen. Effects of potash and phosphate fertilizers on keeping quality were negligible in this experiment at both temperatures. This was not surprising in view of the fact that harvest data showed negligible yield response to potash fertilization and relatively little such response to phosphate.

Results from a replicated experiment pertaining to the effects of washing and bruising upon keeping quality showed a higher percentage of rot for injured roots than for sound ones at both storage temperatures. At 65° the difference was significant. Washed roots kept only slightly better than unwashed roots, the differences being far from significant.

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Harvesting Machinery

Some of the Farm Economic Aspects of Sugar Beet Mechanization[1,2]

H. L. STEWART[3]

Developments in the mechanization of sugar beet production have occurred at a phenomenal rate since the last war. They have made possible the saving of nearly as many man-hours of labor as did the developments made during the entire period between the two great wars, including the shift from horse power to tractors and trucks. In the pre-World War I days of 1910-14, it required about 128 man-hours of labor to produce an acre of sugar beets in the United States. In the pre-World War II days of 1935-39, the production of an acre of sugar beets in the United States required about 97 man-hours, a saving of some 31 hours of labor. Pulling, topping, and loading an acre of sugar beets in 1935-39 required about 30 hours of labor, but today an acre of beets can be harvested and loaded with a mechanical harvester and only 5 to 10 hours of labor.

A study of sugar beet production methods, performance rates, and harvesting costs incurred with the 1947 and 1948 beet crops in selected western areas reveals some of the reasons for the rapid adoption of the mechanical harvester and throws some light on the conditions under which other farmers might find it to their advantage to invest in a mechanical beet harvester. The data presented apply only to some of the more widely adopted machines. They do not include experimental or unadapted machines which were purchased and then left standing in the fence row. It is believed, however, that the performance rates and costs presented are representative of those which other farmers under similar conditions can anticipate with one of the proved machines.

Four types or designs of harvesters are included in the data presented, one two-row machine and three one-row machines. All were "once-over" machines which top, lift, and windrow or load the beets in one operation. The two-row machine, which is used extensively in California, is pulled by a heavy tractor. It employs the principle of a spiked wheel for lifting beets from the ground, after which they are topped and elevated into trucks driven alongside the harvester as it moves through the field. Of the one-row machines, the most common was a tractor-mounted ground topper, which uses a sorting apron and a pulled trailer to carry the beets to the end of the row, where they are elevated into trucks. It was used in all of the areas studied except the Salinas valley. The other one-row harvesters were studied only in Colo-

[1] Data presented in this paper are taken primarily from studies made of the mechanization of sugar beet production in 1947 and 1948 in Weld county, Colorado, and the Salinas and Sacramento valleys of California. Some of the data are taken from a similar study in the Red River valley of North Dakota. The Colorado studies were conducted by Harry G. Sitler and R. T. Burdick; the California studies by Warren R. Bailey and Rex D. Helfinstine; and the Red River valley studies by Roy Gilcreast. These studies were made by the Bureau of Agricultural Economics in cooperation with the State Agricultural Experiment Stations and were financed in part by funds appropriated under the Research and Marketing Act of 1946. The Colorado studies were financed in part by a grant to the Colorado Agricultural Research Foundation from the Beet Sugar Development Foundation. The author assumes sole responsibility for the conclusions and interpretations of the data presented.

[2] Address at the Sixth General Meeting of the American Society of Sugar Beet Technologists, Detroit, Michigan, February 6-9, 1950.

[3] Staff member, Bureau of Agricultural Economics, U. S. Department of Agriculture.

rado. One was a relatively light, tractor-mounted machine which topped the beets in the ground, lifted, and windrowed them. The other was a heavier, pulled machine, which lifted the beets, topped them, and elevated them into trucks driven alongside the harvester.

Labor Requirements and Size of Harvesting Crew

As contrasted with hand harvesting, one-row mechanical harvesters saved around 22 hours of man labor an acre in pulling, topping, and loading beets into trucks in 1947 and 1948.[2] Two-row mechanical harvesters saved about 27 hours (Table 1). Expressed another way, the mechanical harvest required only one-sixth to one-third as much labor as did the hand harvest.

Table 1.—Labor required to harvest and load sugar beets in selected Western areas, 1947 and 1948 crops.

Item	Colorado areas		California areas		
	Manual harvest	One-row mechanical harvesters	Manual harvest	One-row mechanical harvesters	Two-row mechanical harvesters
Yield per acre	18.4 tons	16.8 tons	17.9 tons	16.8 tons	18.5 tons
Hours per ton	1.55[1]	.37	1.84[2]	.59	.29
Hours per acre	28.52[1]	6.22	32.81[2]	9.99	5.40

[1] Loaded with mechanical loader.
[2] Loaded by hand.

The savings in labor tended to be in direct proportion to the yield of beets, as the speed at which the mechanical harvesters were operated generally was not affected materially by the yield per acre, whereas the labor required to harvest a ton of beets manually was relatively constant within the range of yields observed. Hence, in Colorado where 1947 beet yields were unusually high, the amount of labor saved by using mechanical harvesters was higher than can be expected with normal yields. But it is readily apparent that the use of mechanical harvesters means very substantial savings of labor in all of the areas studied.

Mechanical harvesters had the additional and very real advantage of speeding up the harvest. In the areas studied in Colorado, the usual hand pulling and topping crew of 6 workers harvested slightly less than 2 acres per 9-hour day, whereas the one-row mechanical harvesters in both Colorado and California harvested an average of 2.6 acres per 9-hour day. Two-row mechanical harvesters in California harvested an average of 5.8 acres per 9-hour day. There was some indication that the mechanical harvesters were being used as many days during an unfavorable harvest season as were the hand harvesting crews. In Colorado, for example, when frequent storms interrupted the 1947 harvest both the hand harvesting crews and the mechanical harvesters were used on 51 percent of the working days. Mechanical harvesters also can be equipped with lights and a second crew, thereby doubling the speed of the harvest when adverse weather threatens the loss of the crop.

Another advantage of the mechanical harvester, which is less readily measurable in quantitative terms, is the relief which it offers the grower from his dependence on large crews of hired labor. Compared with the usual hand-

[2] Data include labor used in loading beets into trucks in order to assure comparability of all mechanical harvest and manual harvest operations.

topping crew of six or seven workers, the mechanical harvesters required a harvesting crew, exclusive of truck drivers, of only 1 to 3 men, the number employed depending on the kind of harvester used and the harvesting conditions. A few of the growers with each of the different types of harvesters also used one or two gleaners behind the harvester.

Considerable skill is required to operate a mechanical harvester efficiently. Most growers employed a more efficient type of labor for this job than the usual beet worker. Many were operating the harvester themselves. While such work was somewhat more exacting than that involved in recruiting and supervising a large crew of workers, the consensus was that it was more satisfying and less nerve racking.

Table 2.—Amount of beets recovered following hand harvesters and 1-row mechanical harvesters, Red River valley, 1948.

Type of harvest	Number of trials	Yield of beets per acre Pounds	Beets recovered per acre Pounds	Percent recovered Percent
Hand	13	21,505	1,705	7.9
Mechanical, 1-row	48	22,365	1,115	5.0

Efficiency of Mechanical Harvesters

Growers who contemplate a shift to mechanical harvesting are especially interested in the relative efficiency of the two methods in the recovery of salable beet tissue. Although conclusive proof is not available, all of the evidence indicates that mechanical harvesters, when operated properly and under satisfactory conditions, are as efficient as hand harvesting. Mechanical harvesters sometimes get off the row and beets are missed. Faulty adjustments may cause the breaking off of beets, the missing of small beets, or the severance of an undue amount of salable tissue with the crown. But the beet diggers used with the hand harvest also get off the row. And hand toppers also miss beets, especially small ones, and leave salable tissue on the crown. A limited number of random sample tests made in the Red River valley during the 1948 harvest indicate that hand harvesters were leaving more beets in the field than were the 1-row mechanical harvesters (Table 2). While the number of observations was not sufficient to permit safe generalization, they did tend to substantiate the consensus among growers to the effect that proved mechanical harvesters recover as many beets as hand harvesters.

Another bit of evidence is supplied by the experience of a California grower who harvested eight beds of a beet field by hand and an adjacent eight beds by machine. On the machine-harvested beds the yield was 22.0 tons of beets and 74.4 cwt. of sugar per acre. On the hand-harvested beds the yield was 18.8 tons of beets and 69.9 cwt. of sugar.

The use of hand gleaners by custom machine operators in California also is revealing. Custom operators in California employ gleaners as a part of the custom contract to harvest all the beets, but many of them do not employ gleaners when harvesting their own crop.

Growers were of the opinion generally that mechanical harvesters did a more uniform job of topping. The majority felt that there was little difference in the amount of salable tissue left on the crown by mechanical and hand toppers.

The most common criticism of the mechanical harvesters was with respect to the loss of beet tops for livestock feed. This was especially true in Colorado where most of the tops are utilized as livestock feed. These Colorado growers' estimates of the amount of beet tops utilized as feed ranged from 80 to 100 percent when the beets were topped by hand and pastured, as contrasted with 60 to 90 percent when the beets were harvested mechanically. The amount of loss varied considerably by type of harvester but rapid progress is being made by the various manufacturers in the development of attachments and techniques which will help save this valuable feed.

Table 3.—Cost of harvesting and loading an acre of sugar beets with mechanical harvesters, selected western areas, 1947-48.

Item	One-row harvesters		Two-row harvesters
	Colorado	California	California
Number of machines	74	11	18
Acres of beets per machine	39	87	288
Tons per acre	16.8	15.4	16.7
Mechanical harvester costs	$ 8.90	$ 6.03	$ 5.09
Tractor costs	2.02	2.30	2.17
Labor costs	4.70	11.28	6.09
Loader costs	1.68	.....	.....
Total cost	17.30	19.51	13.35[1]

[1] Exclusive of any adjustment for greater loss of beet tops.

Harvesting Costs

Pertinent comparisons of hand and mechanical harvesting costs must include all costs involved, whether they are direct cash costs or indirect costs and whether they are paid at the time of harvest or several years either prior or subsequent thereto. In addition to the direct contract wages, manual harvesting costs include the cost of bonuses and of the various prequisites furnished the workers. Mechanical harvesting costs include, in addition to cash wages and the cost of fuel and repairs, a wage for the operator and unpaid family labor and such overhead items as depreciation, interest on investment in the equipment involved, taxes, insurance, and shelter.

Many of these indirect costs are not directly calculable. Considerable care has been exercised in their calculation in order to assure comparability with costs calculated for other methods. But the costs for the same method of harvesting are not necessarily comparable between different areas as it has not been possible to assure absolute comparability between areas in all of the numerous judgments involved in calculating the indirect costs.

Costs of harvesting an acre of sugar beets with a one-row mechanical harvester averaged only 49 percent of the manual harvesting costs in both the Colorado and the California areas. Per acre harvesting costs with a two-row mechanical harvester in California averaged only 34 percent of the hand harvesting costs. As contrasted with hand harvesting costs which averaged $39.65 in California and $35.51 per acre in Colorado, one-row mechanical harvesting costs averaged only $19.51 in California and $17.30 in Colorado, while two-row mechanical harvesting costs in California averaged only $13.35 per acre (Table 3).

Many factors affect the costs of using mechanical harvesters. Among the more significant factors which sometimes are overlooked in cost comparisons are the yield of the beets harvested, the acreage of beets harvested each season, and the length of life of the machine. The yield of beets harvested affects primarily the cost per ton—the higher the yield the lower the cost per ton (Table 4).

Table 4.—Effect of yield on cost of harvesting and loading an acre of sugar beets with a one-row mechanical harvester, selected areas in Colorado, 1947-48[1]

Yield per acre (tons)	10	12	13	14	16	18	20
Harvesting cost per ton	$2.60	$2.19	$2.03	$1.89	$1.67	$1.49	$1.36
Harvesting cost per acre	26.00	26.28	26.39	26.46	26.72	26.82	27.20

[1] Assumes 20 acres of beets harvested annually.

The acreage harvested annually affects such costs as depreciation, interest on investment, taxes, insurance and shelter. Since the annual charge for such items is fixed, the cost per unit harvested declines as the acreage harvested increases (Table 5). Similarly, the purchase price of the machine is fixed, and, as the length of life of the machine is increased, the annual depreciation cost is decreased. In Colorado, for example, with 1947-48 cost rates and with an assumed annual harvest of 25 acres of beets yielding 13 tons per acre, the annual harvesting cost with a one-row mechanical harvester would be $30.55 an acre if the life of the machine were 5 years. It would be only $22.36 an acre if the life of the machine were 10 years (Table 6).

Table 5.—Relationship of harvesting and loading costs with a 2-row mechanical harvester to acreage of beets harvested annually, selected areas in California, 1949[1].

Acreage harvested per year	Harvester costs per acre			Total harvesting costs per acre
	Fixed[2]	Variable[3]	Total	
50	$14.07	$2.40	$16.47	$24.97
100	7.04	2.40	9.44	17.94
150	4.69	2.40	7.09	15.59
200	3.52	2.40	5.92	14.42
250	2.81	2.40	5.21	13.71
300	2.35	2.40	4.75	13.25

[1] A new machine costs $5,500 and is assumed to have a salvage value of $500 at the end of its useful life. The assumed length of life is 10 years and the assumed yield per acre is 17 tons.

[2] Includes depreciation, interest on investment, taxes, insurance and shelter, costs which are fixed in the sense that they represent a fixed annual charge irrespective of the acreage harvested.

[3] Includes all other harvester costs such as fuel, labor, etc., which vary directly with the acreage harvested.

The depreciation costs of mechanical harvesters are difficult to determine because the harvesters have not been in use long enough to provide an adequate basis for estimating their length of life. Also, the machines are being improved constantly and obsolescence may shorten the period of usefulness and thus increase the depreciation costs of current machines. Based largely on observations and the judgment of machine owners who have been using a mechanical harvester for a number of years, the life of machines is assumed to be 10 years in the cost calculations presented here. Because of the obsolescence factor, the life of machine is assumed to be 10 years for all machines irrespective of the annual usage.

Justifying a Mechanical Harvester

In determining whether it would be economic to buy a mechanical beet harvester most growers are interested in determining whether, after

Table 6.—Relationship of harvesting and loading costs with a 1-row mechanical harvester to length of life of the harvester and acreage of beets harvested annually, selected areas in Colorado, 1947-48[1]

Acreage harvested annually	Costs per acre with assumed life of machine of	
	10 years	5 years
Acres		
10	$46.02	$65.91
15	32.89	46.28
20	26.39	36.40
25	22.36	30.55
30	19.76	26.52
35	17.94	23.79
40	16.51	21.71
45	15.47	20.02

[1] A new machine costs $2,500. The assumed yield per acre is 13 tons.

allowing for all costs, they would be ahead over a period of years in terms of dollars by shifting from hand to mechanical harvest. We have already seen that mechanical harvesting costs are affected greatly by both the acreage and the yield of beets harvested and, since per unit hand-harvesting costs are much more stable, the most significant determinants (assuming a given level of wages and cost, and life of machine) are the acreage and yield of beets harvested annually.

To the extent that relative labor and machine costs remain unchanged from those prevailing during the period of study, and to the extent that the margin of profit which mechanical harvesters earned for growers in 1947 and 1948 is not passed on to others through reduced prices, the comparative costs developed should provide other growers operating under similar conditions with a fairly reliable guide to the relative costs to be expected under actual farm conditions. It should be recognized, however, that the machine costs apply to proved machines adapted to the areas in which they were used, and that they assume that the grower already has a tractor for other farm work. Also, they assume the grower has a free choice of investing in wages for hand laborers or in the purchase and operation of a machine.

On the basis of 1949 cost rates, California growers who are assured of an annual harvest of 25 or more acres of beets yielding 17 tons or more to the acre would appear to be justified in the purchase of a mechanical harvester; that is, their harvesting costs would be expected to be lower than hand harvesting costs. Those who are assured of an annual harvest of 25 to about 100 acres annually probably would find it most economical to purchase a one-row harvester. The one-row harvesters included in the California study harvested an average of 87 acres annually. They are capable of harvesting some 125 acres in such areas where they probably can be used 50 full days during most harvest seasons. California growers who have an annual harvest of 100 or more acres probably would reduce their harvesting costs most by purchasing a two-row harvester if they already have a tractor large enough to handle the heavier machine (Table 7). A two-row machine harvests about

250 acres in a season of 50 harvesting days. As an average, those included in the California study harvested 287 acres per season.

Table 7.—Comparative costs per acre of harvesting sugar beets with 1-row and 2-row mechanical harvesters, selected areas in California, 1949[1].

Acres harvested annually	Harvesting cost per acre	
	One-row harvester	Two-row harveste.[2]
Acres	Dollars	Dollars
25	29.45	[3]
50	22.35	24.97
75	19.99	[3]
100	18.80	17.94
125	18.09	[3]
150	17.62	15.59

[1] With an assumed yield of 17 tons per acre and an assumed life of mechanical harvesters of 10 years.
[2] Does not include any adjustment for greater loss of beet tops with two-row harvester.
[3] Not calculated.

On the basis of 1947-48 cost rates, Colorado growers who are assured of an annual harvest of 20 or more acres of beets yielding 13 or more tons per acre would appear to be justified in the purchase of a one-row mechanical harvester if they already have a tractor for other farm work and if, as assumed, the service life of the harvester proves to be 10 years (Table 8). If the service life of the harvester should prove to be only 5 years, the Colorado grower would need an annual harvest of some 30 or more acres of 13-ton beets to justify the purchase of a mechanical harvester. The machines included in the Colorado study harvestd an average of 39 acres each season.

What about custom harvesting as a means of reducing costs of smaller growers? Thus far, custom harvesting rates in the areas studied have been based largely on current hand harvesting rates. At such levels small growers have had little financial incentive to shift from hand harvesting. As the number of mechanical harvesters increases, however, custom harvesting rates doubtless will be lowered. Small growers will then have a financial incentive to shift from hand harvesting, as well as such other advantages as are realized in a faster harvest, and a harvest which does not depend on a large number of workers. Even if mechanical harvesters should increase to the point that the beet harvest no longer attracts laborers to an area, the small grower probably will have several alternatives. He can increase his beet acreage enough to justify the purchase of a mechanical harvester; he can do enough custom harvesting for his neighbors to justify the purchase of a harvester; or he can hire his own harvesting done on a custom basis.

Prospects for the Future

The success of the mechanical sugar beet harvester has been assured by its effectiveness in reducing harvesting costs. It is economic on smaller acreages than once were considered necessary. While it still is subject to additional improvements, the mechanical beet harvester is here to stay.

With the harvest mechanized, the greatest remaining opportunity in mechanizing sugar beet production lies in the mechanization of the spring work, the blocking, thinning, hoeing and weeding. These operations still are done largely by hand. They require some 28 to 30 hours of arduous labor per acre. Concerted efforts are being directed toward the improvement of

beet seed and planting equipment, effective sprays, and improved machines which will reduce the labor and costs involved in these operations. Prospects

Table 8.—Cost per acre of harvesting and loading sugar beets by hand and with a one-row mechanical harvester, selected areas in Colorado, 1947-48[1].

Acres harvested annually	Harvesting cost per acre		
		Mechanical harvester	
	Hand harvest[2]	10-year life	5-year life
Acres			
10	$33.15	$46.02	$65.91
15	31.33	32.89	46.28
20	30.42	26.39	36.40
25	29.90	22.36	30.55
30	29.51	19.76	26.52
35	29.25	17.94	23.79
40	28.99	16.51	21.71
45	28.86	15.47	20.02

[1] With an assumed yield of 13 tons per acre.
[2] Beets loaded with mechanical loader.

are remote for the complete elimination of hand labor in this spring work but it seems probable that it will be reduced to a once-over, long-handle hoe operation, requiring only four or five hours of labor per acre. Limited observations in the Colorado study show that mechanical blocking, even under adverse circumstances, reduces the labor required in blocking and thinning by 40 percent.

What about the effects of sugar beet mechanization on the organization of beet farms and the location of our beet acreage? In many of the established beet areas in the west the acreage of beets already is at its optimum level, that is, it cannot be expanded materially because of crop rotation or water requirements. In Yolo county, California, for example, growers have learned that it is unwise to grow beets more often than every third or fourth year on the same land because of nematodes and other pests—yet out of 100,000 acres of irrigated land in the county, 31,594 acres were in sugar beets in 1948. In such areas mechanization probably will have no significant effect on the total acreage of sugar beets even though it may encourage a few new growers to produce beets and a few of the smaller growers to expand their acreage.

If acreage control programs permit, it does seem likely that mechanization will encourage an expansion of beet production in new areas, especially in some of the newly irrigated areas of the west. Such areas need an intensive row crop in their rotation. They need a crop which will encourage livestock production and help build up and maintain their soil fertility. Sugar beets are such a crop. With sugar beet production mechanized, farmers in these areas would be able to get into beets without the labor problems which have been associated with them in the past. In both the new and the established irrigated areas, the mechanization of beet production, together with the recent development of irrigated pastures and other technological developments, offers an opportunity to develop a farm program which provides year round employment for a few workers rather than just seasonal employment for many.

Engineering Developments on the International Sugar Beet Harvester

J. L. HIPPLE[1]

This paper will deal with the improvements and engineering development work on the International sugar beet harvester over the past two harvest seasons.

Several efforts were made to lighten the weight of the topper unit to make it more active, to better top beets of irregular heights—none of which was entirely successful—so a driven belt finder was developed and adopted as a special feature to be used where it will work better than the drag type finder, which had a tendency to knock over beets growing in loose soil, causing side slicing instead of correct topping.

Figure 1. Front view of the International harvester.

One hundred of these driven belt type finders were made for the season of 1949. This unit consists of a 6-inch corrugated rubber belt driven by a roller chain at a speed a little greater than ground travel. It runs over special skeleton type rollers to prevent mud building up on the rollers.

One very interesting development on topper design was tried for the first time this year. Several objectives were sought in this new design. We attempted to combine the driven finder principle with a top disposal unit and to make a more compact unit so that space would be left between it and the puller points for a beater to clean off the side growth.

This unit consists of a drum 18 inches in diameter and 9 inches wide, driven by a roller chain. Conventional receding pickup fingers are built

[1] J. L. Hipple, International Harvester Co.

Figure 2. Beets dug and topped by International's harvester.

into the drum. They are fully receded into the drum at the point of contact with the beet, providing a smooth roller effect. The drum, being driven slightly over ground speed, tends to hold the beet crown while the knife is cutting.

A stationary topping knife is used in the design, which is a departure from our rotating disk type. We hope that the driven drum finder and pickup springs will keep our topping knife clean and allow us to top beets in all conditions without the use of the driven disk. Our tests so far have been very encouraging.

As the drum rotates, the pickup fingers protrude quite rapidly and pick up the tops and crowns, carrying them up to the top of the drum where they are swept off onto a conveyor belt. So far, we have only carried the tops out beyond the track of the tractor wheels, but several methods can be usd to windrow the tops or convey them directly to a wagon or rack driven alongside while the top growth is heavy and still green. This could very easily be an economical method of recovery.

Figure 3. The International machine in action.

This unit was tested first last May at Calexico, California, and later in the fall at both Grand Forks and Saginaw. It looks quite promising, and we plan an extensive test this next harvest season.

We made several efforts to recover the tops successfully from the disk type of topper unit—but we were satisfied with none of these trials. Our engineers in France did considerable work on a different type of topper unit, mostly in an effort to harvest successfully beets in Holland and Belgium. A driven drum and stationary knife was used in these efforts, but work on the project has been stopped since it appears that the design just described will work successfully.

Next year's test models will include a beater to clean off the side growth and different means of placing the tops from the conveyor belt. Other changes in the production harvester include: slowing down the sorting belt to allow more time for sorting, and adjustable wheels in the cart to allow tread settings to better fit various row spacings.

Development of a Simplified Tractor-Mounted Sugar Beet Harvester

E. F. BLACKWELDER[1]

Early in 1947 the first Marbeet "Midget" tractor-mounted beet harvester was built and tested. Following testing in the Imperial valley eight machines were built and shipped to the principal beet-growing areas in this country. During the testing of these machines, under practically every type of condition, it was apparent that improvements were necessary.

During 1948 changes were made and testing continued in Utah, Idaho, and California; with marked improvement over the prior year. Nevertheless, performance and quality of work failed to warrant a production and marketing program. Our conclusion during this season was that the excessive draft, resulting in side draft and consequent difficult steering, was the basic cause of poor performances.

The cause of the high draft and how it was overcome can best be explained through a description of the design and operation of the machine. In principle we employ the same methods as are used in our larger models. That is, plows are used to loosen the beets, which are then lifted by a spiked wheel and topped. The main difference between the older or larger machines which are of a trailer type and the new small tractor-mounted units are found in the principle on which the plows function and in the 30-inch diameter wheel which replaces the original six-foot wheel. It was necessary in our older models to run the plows from 11 to 13 inches deep in order that the beets and ground might be loosened so the large heavy wheel could push the beets to the ground level before lifting. In the small machine the lifting plows are set to run at an average depth of 5 inches and lift the beets to the wheel. In order that the 30-inch wheel can pull the beets without breakage, it is necessary for the plows to lift them 3 to 4 inches before they are spiked.

The Midget is mounted on the right hand side of a wheel tractor between the front and rear axles, using the rear housing as a foundation to support the mounting brackets. During the first two years of development the main and sub-frames used the tractor axle as a common center for hinge points. The pickup wheel is mounted on the secondary frame, which is permitted to float independently of the main frame which supports the plows. The floating action of the inner frame permits the wheel to rise to the high crown beets and drop to the smaller ones. The pickup wheel is ground driven by a roller chain running over a sprocket mounted on the rear axle. As the beets are lifted to the wheel they are carried around to the top where they are lifted to a common height by three strippers, each mounted between a row of spikes, and then topped by two driven topping discs. The beets are then carried around to a potato chain conveyor, mounted inside the right hand rear wheel, which carries the beets back into a trailer

[1] Manager, Blackwelder Mfg. Co., Rio Vista, Calif.

cart. The crowns and tops are then stripped from the wheel and deposited on a cross conveyor belt which windrows them in an orderly row where the tractor wheels will not run over and trample them into the ground.

The trailer, holding about 1¼ tons of beets, is carried on two rubber-tired wheels, the left of which is adjustable to fit row spacing. The cart is unloaded by a potato chain elevator driven from the tractor power take-off, and can be operated as desired either at the ends of the field or as the machine is being operated down the row.

Since it had become evident that heavy draft was the basic limitation to good performance, the solution of this problem assumed major importance. A study revealed that the heavy draft was caused by the difference in ground speeds between the tractor wheels and the spiked pickup wheel. This difference was found to vary widely in different soil conditions, and could not be corrected by changing sprocket ratios. Also, the manner in which the secondary frame carrying the pickup wheel was hinged created a torque whose resultant force was a downward thrust on the pickup wheel. As the driving torque was high due to the differential speed between the tractor rear wheel and the pickup wheel, an excessive pressure was exerted upon the beets as they entered the lifters. This in turn caused more draft, further increasing the torque, and finally resulted in enough resistance to cause the opposite tractor wheel to spin. This also would prevent the plows from lifting the beets the necessary distance before spiking them, with consequent breakage and the loss of beets.

It has been pointed out that in 1948 the frames were hinged so that the tractor axle was their common center, which point was considerably above a line parallel to the ground running through the center of the pickup wheel. We found, by dropping the hinge point below the tractor axle to the plane of the parallel line, that the wheel is raised instead of being pulled down when the pull of the chain drive exceeds the weight of the pickup wheel assembly. This also automatically takes care of the difference in the ground speeds between the tractor wheels and the pickup wheel. This changes the effective rolling radius of the pickup wheel. These changes made it possible to accomplish a job of harvesting under most conditions with a tractor having a drawbar pull as low as 25 horsepower.

Fourteen "Midgets" were built, sold and operated during the 1949 campaign with quite satisfactory results. Two machines were used in Tucumcari, New Mexico; one on a Farmall "M," the other on an Allis-Chalmers "WD." The results were most encouraging.

The machine at Torrington, Wyoming, was mounted on a Farmall "H" and used on four different contracts. It harvested 45 acres and delivered 696 net tons with an average tare of 4.49%. Harry Watson, the grower, harvested his crop with one hired man driving the trucks. The harvesting was done during some very mild weather, also during rain and snow. The only disappointing part of this experience was that our recovery was not entirely satisfactory. A few beets were left in the field but Mr. Watson's wife was in the field part of the time and she easily recovered all the dropped beets. The Farmall "H" operated in second gear most of the time except at one end of his largest field, which was very wet.

At Preston, Idaho, and Murray, Utah, we had a machine each mounted on an Allis-Chalmers "WD," and from which we have had very encouraging reports. The most notable features of these performances were that during the rainy and wet weather it was necessary to put skid chains on the tractor rear wheels, but they were able to continue to harvest whenever it was possible to drive a tractor into the field.

The nine California machines were operated under all types of field and weather conditions. I will review the performance of two of these machines which I believe are quite representative.

The Midget owned by J. M. Marshall at Clarksburg was operated on heavy soil, yielding a 28-ton per acre crop. He harvested his entire 100 acres with two men, each taking a turn operating the harvester, loading a truck and then delivering to the factory, which is only a short haul. They were operating on a 50-ton quota which usually was delivered by early afternoon and on many days before noon.

The machine owned by Glenn Wesner of Liberty Island was mounted on a Farmall "H." It harvested 175 acres and delivered 3,450 net tons of beets. The repair parts cost was $60.53, or $.346 per acre or $.017 per ton. Mr. Wesner reports the net cost of all beets delivered into the truck was 45c per ton. This includes all charges, even depreciation. One hundred thirty-nine net tons in a single nine hour day was his delivery record. Of this time there were usually about thirty minutes needed for daily servicing. It is reported that this machine delivered cleaner and better topped beets with less trash than any other machine delivering beets to this particular dump. (This may not be significant to most of you when it is explained that all other machines were the large Marbeet harvesters.) The average tare of beets delivered by this Midget was 3.75% on the Wesner contract.

Fifteen hundred seventy-five acres were harvested by twelve Midgets on which records were kept, an average of 131 acres per machine, from which average 28,350 net tons of beets were delivered, or 2,362 tons average per machine.

The harvester as now designed can be mounted on the following makes of wheel tractors: Allis-Chalmers "WD," Farmall "H" and "M," and John Deere "AW" and "GW." It is our plan to have machines available for all the popular makes of wheel tractors having horsepower equivalent to the above tractors. The complete harvester mounted on the tractor, including trailer, weighs 3,539 pounds.

Arrangements are now being made with dealers in the various beet growing areas to sell and service our equipment. This program will be expanded gradually as the interest shown by processors and growers justifies it.

Experiences with Mechanical Harvesters and Beet Top Baling

ART JOHNSON[1]

The year 1949 was characterized by a mass movement of Holly Sugar Corporation's California growers toward grower-ownership of harvesters. Contract harvesting continued at about the 1948 scale and accounted for 15% of the total acreage harvested mechanically.

Table 1 shows the steady expansion of mechanical harvesting of Holly's California acreage:

Table 1.

Year	% of Beets Mechanically Harvested
1949	78
1948	74
1947	69
1946	60

Practically all of the harvesters bought in 1949 were of "Marbeet" manufacture, i.e., junior 1-row, standard 1-row, Midget tractor-mounted 1-row and standard two-row.

It has been found generally that growers who own their harvesters conduct a more efficient operation than those who rent company-owned machines. Because it is their own equipment they employ higher calibre operators and supervise the operation more carefully. Consequently, the per-acre cost for parts and repairs is considerably less for grower-owned machines. Many more acres per machine were harvested by grower-owned harvesters than by company-owned harvesters. The reasons were that growers with large acreages preferred to have their own harvesters, whereas most of the company-owned harvesters had to serve several growers, some of them small, and time was lost in moving from field to field.

An outstanding example of the economy of operation of a grower-owned two-row Marbeet harvester is that of a grower who harvested 600 acres near Stockton with a parts and repairs cost of 37c per acre. This grower's average harvest in a 9-hour day was 16 acres or 275 tons of beets. Only 4 hours were lost during the entire harvest period due to breakdowns.

Another outstanding performance, this one by Marbeet junior harvesters, was accomplished in an Imperial valley field in which a pair of these machines harvested 570 tons of beets in a 12-hour day. The two foregoing performances are out of the ordinary, but they show what can be done by first class operators under satisfactory conditions.

[1] District Agriculturist, Holly Sugar Corporation, Stockton, California.

Table 2 gives the record of performance of machines used in Holly's California fields in 1949.

Table 2.

	Acres Harvested By					
	Holly-Owned Grower-Operated	Contract Harvesters	Grower-Owned and Operated	Total Acres	Number Units	Av. Acres Harvested Per Unit
Marbeet Junior	2,747	656	6,235	9,638	118	82
Marbeet Standard	770	373	1,724	2,867	34	84
Marbeet Two-Row	231	3,255	16,128	19,614	47	417
Marbeet Midget	.....	.....	344	344	4	96
International	.....	1,130	850	1,980	10	198
Scott-Urschel	51	.....	28	79	2	40
Totals	3,799	5,414	25,309	34,522		

With each successive year of mechanical harvesting growers are becoming more aware of the success of operation in the absence of weeds. Consequently, each year since the advent of mechanical harvest has seen an improvement in the cleanness of sugar beet fields. The defoliator is being used on machines wherever it is necessary to remove grass and other weeds in order to get at the beets, but farmers are finding that clean cultivation and not the defoliator will go farthest in solving their weed problem. The value of beet tops and the proved practical ways of handling them are now being recognized to the extent that there will be less defoliation of beets and more saving of the entire top by the harvester.

From the point of view of efficiency and all-around satisfactory operations, it cannot be emphasized too strongly that the grower should own the harvesting equipment rather than the sugar company.

In view of the wage rates for hand labor in most areas, growers are wholeheartedly appreciative of any and all modes of harvest mechanization. Numbers of grower-owned harvesters are increasing steadily on all except the very smallest farms, and the Marbeet midget, or other small machine, in the hands of a contract operator stands a good chance of covering the remainder of this small-plot acreage.

Complete mechanization has come closer to realization in the new districts because new growers are more receptive to new ideas. There is no obstacle in the way of mechanization when the grower is sure in his own mind that it saves him money. The machine which can do the best job of delivering well-topped beets, large or small, and a windrow of dirt-free tops, will be the one which gets the grower's vote.

The most nearly perfect job of handling beets tops so far observed was carried out in the fall of 1949 near Rio Vista by the California Packing corporation.

The beets were harvested by two-row Marbeet harvesters. The windrowing attachment was operated so as to lay the tops from double rows of beets in a single windrow. In a separate tractor operation, a heavy steel roller was pulled over the ground already harvested and just ahead of the windrower. It made a round to each 2 rounds of the harvester and smoothed

the ground so that the tops fell on a level, compact surface. The tops were allowed to lie where they were windrowed until they were partially cured, and then 2 windrows were put together with a side-delivery rake. After a period of drying, totalling about 14 days from the time of harvest, the tops were ready for baling. During this 14-day period it was sometimes necessary to turn the whole windrow once with a rake to insure thorough curing.

A Case 3-wire pickup baler was used and made bales of about 225 lbs. each. This baler handled the tops with very little adjustment after having baled alfalfa. A smaller (International) 2-wire baler was also used. It made bales weighing about 85 lbs. Altogether, about 500 tons of dried tops were baled on this ranch. From 1¾ tons to 2 tons of baled tops per acre were obtained from beets which yielded 16 tons to the acre. Immediately after baling the product was hauled to a stack lot.

When the bales were later broken open it was found that the material was dry enough so that no molding or other form of decomposition had taken place. The amount of dirt included with the tops was almost unnoticeable. The dirt was shaken out of some bales and weighed to find out how much dirt there actually was, and it amounted to only 2 to 3% of the weight of the bale. It was thought that this could be eliminated almost entirely by using a slotted slide in the baler.

The material was not quite dry enough to grind in a hammer mill, but chopped up nicely when put through a Bear-Cat hay chopper. The fattening cattle at it with great relish when it was fed either alone or chopped with barley hay.

Table 3 shows an analysis of the baled tops.

Table 3.

Protein (N x 6.25)	6.83%
Fat (Ether Extract)	1.86%
Crude Fiber	7.80%
Ash[1]	29.77%
Moisture	12.17%
Nitrogen-free Extract	41.57%
	100.00%

[1] Includes any dirt which might have been in the sample.

Sugar Beet Harvester Performance in American Crystal Sugar Company Territory in 1949

EDWARD L. SWIFT[1]

The number of mechanical sugar beet harvesters operated in American Crystal Sugar Company territory has increased greatly each year over the preceding year since 1942. Prior to 1949, the tonnage harvested mechanically more or less kept pace with the number of harvesters operated, but the tonnage harvested by machine in 1949 was much less than was expected from the number of machines in operation. This reduction in performance was partly due to the extremely dry soil condition in some areas in 1949, and also because of a surplus of field labor in some districts (particularly California). Because of this labor surplus, growers who normally waited for their neighbors to harvest their crop after completing their own beets harvested their beets with hand labor. Also, the beet harvest was completed in most districts in a much shorter period than normal, which also contributed to the lower tonnage output per harvester.

During the past seven years the following numbers of beet harvesters were operated in American Crystal Sugar company territory:

1943—9	**1944—36**	**1945—82**	**1946—172**
1947—305	**1948—565**	**1949—671 machines**	

The distribution and output of these 671 mechanical beet harvesters used in American Crystal Sugar Company territory during 1949, by makes, was as follows: The 69 Marbeet harvesters and 5 Marbeet midgets harvested beets in the dry soil conditions of California, the Marbeet machines averaging 3,690 tons of beets and the midgets averaging 1,300 tons per harvester. The 42 John Deere machines, which were operated in the lighter, more friable irrigated soils of Montana and Nebraska, averaged 435 tons of beets. The 427 International machines which were operated in all of our factory districts under all soil conditions harvested a total of 317,282 tons of beets, or an average of 745 tons per harvester. The Scott-Urschel harvesters were operated chiefly in the non-irrigated areas of Minnesota and Iowa, the 107 machines harvesting an average of 615 tons of beets per machine. The Harvall machines were operated only in the Red River valley of North Dakota and Minnesota in non-irrigated beets, each of the 16 machines averaging 807 tons beets harvested. An additional 5 harvesters of miscellaneous make (three of which were Kiest) harvested a total of 994 tons of beets. Thus, 671 machines harvested a total of 676,757 tons of beets during 1949, or an average of 1,009 tons of beets per harvester.

Any of these commercial machines, if operated properly under reasonable soil moisture conditions, will deliver clean, well topped beets which

[1] Special Agriculturist, American Crystal Sugar Co.

are free of trash and suitable for processing or storage. The quality of work from similar machines varies directly with the skill of the operators.

Beets from mechanical harvesters have been found to keep in storage as well as or better than hand topped beets. Generally, beets harvested mechanically are delivered to the receiving stations within an hour after being lifted. These beets are cool and have not been dried out as is the case with hand topped beets which have been exposed to the air and sun for a considerable time. The tare on mechanically topped beets is generally comparable with that of hand harvested beets.

The condition of the sugar beet tops as left after mechanical harvest is important in most districts. Beet tops from approximately 48% of the 1949 harvested beet acreage were fed to livestock. If mechanical top saving devices can be further improved, undoubtedly a greater part of the beet tops will be utilized for feed. The top saving mechanisms on all of the harvesters, possibly excepting the John Deere, need to be improved. The common objection by growers to mechanical harvesting is the poor condition of the beet tops.

In the area served by the American Crystal Sugar Company's nine factories, the percentage of mechanically harvested beets during 1949 varied in proportion to the physical condition of the soil and the availability of hand labor. By areas, the percentage of mechanically harvested beets in tonnage was as follows:

California: 69.4%—which was distributed by factory areas: Clarksburg, 73.6%; Oxnard, 41.4%; and Imperial valley, 60.5%.

Intermountain: 55.7%—which was distributed by factory areas: Missoula, Montana, 70.9%; Rocky Ford, Colorado, 45.6%; and Grand Island, Nebraska, 55.7%.

Eastern District: 38.7%—distributed by districts as follows: Mason City, Iowa, 50.9%; Chaska, Minnesota, 63.1%; and the Red River valley, 35.8%.

While mechanization of harvest operations has lagged somewhat in the Red River valley, that area has led the country for a number of years in mechanizing spring operations by the use of precision drills, pencil weeders and ridge covering of seed, mechanical thinning and cross cultivating operations to reduce or eliminate hand thinning and hoeing of beets. Beet growers would prefer to mechancally thin their beets provided a suitable harvester is available which can successfully handle multiple beets. It is believed that at long last this obstacle to complete mechanization of the sugar beet crop will be overcome through the large scale utilization of the Harvall harvester, which performed in a highly efficient and satisfactory manner in the Red River valley in 1949 despite extremely dry soil conditions. It also proved satisfactory in muddy fields. At the present time it is anticipated that several thousand acres of beets will be thinned and harvested mechanically in this area in 1950, with no hand labor except for the necessary hoeing operation.

Sugar Beet By-products

Studies of Beet Top Silage In Lamb Fattening Rations[1]

LIONEL HARRIS AND M. A. ALEXANDER[2]

During the seven-year period 1942 to 1948 sugar beet tops from the irrigated rotation experiments at the Scotts Bluff Substation, Mitchell, Nebraska, were harvested for silage. The yield of edible silage during this period was approximately 50 per cent of the yield of beet roots in certain roatations (1)[3]. In some instances the yield of fresh green tops exceeded the yield of roots. Similar results have been reported by Wilgus et al. (2).

Experiments by Dunn and Rost (3), Guilbert et al. (4), and Wilgus (2) indicate that the feeding value of beet tops is equal to that of alfalfa hay on a dry matter basis. Field-cured beet tops have been used successfully in replacing approximately three-fourths of the alfalfa hay in rations for dairy cattle (5). High values have been reported for beet tops in cattle and lamb feeding rations (6).

Ensiling sugar beet tops should preserve much of their original feed value (4) (7) (8). However, the practice of silage production with sugar beet tops has not been adopted on a wide scale up to the present time. A survey conducted by the Beet Sugar Development Foundation (9) showed that less than one percent of the beet tops were ensiled. This survey also showed that more than 50 percent of the tops were left in the field and pastured, or plowed under.

Early reports (10) (11) on the making of silage refer to dirt and excessive moisture as factors influencing quality. Some of these reports also refer to excessive scouring in lambs fed beet top silage.

This paper reports the results (a) of feeding beet top silage in comparison with corn silage in lamb fattening rations, and (b) the results from feeding beet top silage as the only roughage in comparison with beet top silage and alfalfa as roughage for fattening lambs. The work was conducted during the period 1943 to 1948 at the Scotts Bluff Substation.

METHODS OF MAKING SILAGE

During the period 1943 to 1947 the beet tops were ensiled whole. In 1948 the tops were chopped with an ensilage cutter before ensiling. The beet tops were ensiled in a pit silo on top of corn silage during all years except 1943 and 1944, when they were ensiled in a stack. The beet tops were harvested for silage production from one to ten days after the beets were topped with the exception of 1947 when snow delayed harvest of the tops for approximately 30 days.

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[1] Contribution from the Nebraska Agricultural Experiment Station, Lincoln, Nebr., and the Division of Soil Management and Irrigation, Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture, cooperating. Published with the approval of the Director as Paper No. 499, Journal Series, Nebraska Agricultural Experiment Station.

[2] Associate Agronomist, Bureau of Plant Industry, Soils, and Agricultural Engineering and Superintendent of the Scotts Bluff Substation; and Professor of Animal Husbandry in charge of sheep investigations, Nebraska Agricultural Experiment Station.

[3] Numbers in parentheses refer to literature cited.

Waste due to mold and excessive heat was greater in tops ensiled in the stack than in the pit. Most of the tops to a depth of six to twelve inches on the outside of the stack were moldy, or dark brown or black in color. In the pit silo the beet top ensilage was uniform and generally of very good quality. The quality of the silage produced inside of the stack appeared to be as good as that produced in the pit silo.

Some waste occurred in feeding whole beet top silage to lambs. The waste occurred when lambs took hold of an ensiled sugar beet leaf and pulled it and the entire crown out of the feed bunk onto the ground. During 1947, when the tops remained in the field for approximately 30 days after topping, a rather large amount of waste occurred in feeding the beet top silage. During this year the beet top crowns appeared to be firmer and less palatable than in other years when the tops were ensiled within a period of ten days after topping. In 1948 no waste occurred in feeding the chopped beet top ensilage produced in a pit silo.

During the years when beet tops were stacked on the ground, a rather large amount of moisture leaked out the bottom of the pile. When the tops were placed in a pit silo on top of corn silage the excess moisture undoubtedly leaked out into the corn silage.

Corn silage was made by chopping green corn with an ensilage cutter and placing it in a pit silo. During most years the corn silage was made from corn which would yield from 70 to 80 bushels of corn per acre. During 1945, because of a heavy hail storm during June and an early frost in the fall, corn in the milk stage was harvested for silage. The gains of lambs fed this silage were not satisfactory.

The moisture content of both the corn silage and beet top silage ranged from 69 to 73 percent during the years the feeds were studied.

EXPERIMENTAL PROCEDURE

Lambs Used

White-faced feeder lambs from Wyoming were used in these tests during all years except 1948 when black-faced feeder lambs from western Colorado were used. The lambs were divided into uniform lots as nearly as possible. The factors of weight, sex, and condition were considered in making the allotments. Light weight, heavy weight, and unthrifty lambs were not included in the tests.

The lambs were weighed individually on two consecutive days at the beginning and end of each test to obtain initial and final weights. Also, during each test individual weights were taken at approximately 28-day intervals.

Methods of Feeding

Concentrates and roughages were fed twice daily in regular sheep feeding bunks. The silage allotment was distributed along the bunk first, followed by grain and concentrates, and finally alfalfa hay where this feed was used. The feeds were then mixed in the feed bunk with a fork. Each kind of silage was fed according to the appetite of the lambs and their ability to consume it in addition to a basic ration. No attempt was made to feed the two kinds of silage on an equal weight basis.

Prices of Feeds

Prices used in determining the cost of 100 pounds of gain represent mean prices paid by the Scotts Bluff Substation for the feeds used during the period 1943 to 1948. These mean prices were as follows: Grain mixture (equal weights of corn, barley, and dry sugar beet pulp) $2.15 cwt.; corn, $2.50 cwt.; cotton seed meal, $3.80 cwt.; soybean meal, $3.75 cwt.; bone meal, $4.00 cwt.; and alfalfa hay, $16.00 ton. The price of corn silage and beet top silage was established on the basis of one-half the value of alfalfa hay, or $8.00 per ton.

DISCUSSION AND RESULTS

I. Comparison of Beet Top Silage and Corn Silage

Basal Ration: Shelled corn, cotton seed meal, bone meal and alfalfa hay.

The results of this comparison for 1946 and 1947 are shown in Table No. 1. In 1946 two groups of 50 lambs each were fed for 108 days, and during 1947 two groups of 45 lambs each were fed for 102 days. The initial weight of the lambs was approximately 60 pounds in 1946 and 70 pounds in 1947.

The average daily gain of the lambs fed corn silage was .34 pounds each year, compared with .35 pound for the lambs fed beet top silage in 1946 and .32 pound in 1947. Differences in daily gains between lambs fed the two kinds of silages in this comparison were not significant. During the two-year period the average daily intake of corn silage was 2.23 pounds per lamb, compared with 3.64 pounds of beet top silage.

Feed required per 100 pounds of gain was similar for the two lots of lambs in respect to corn, concentrates, and alfalfa hay. However, the consumption of corn silage per 100 pounds of gain was 653.5 pounds, compared with 1,091.0 pounds of beet top silage. The high consumption of beet top silage resulted from a rather large waste of beet tops fed in 1947. The feed cost per 100 pounds of gain for lambs fed corn silage was $15.18, compared with $17.13 for lambs fed beet top silage. The difference in feed costs reflects the large waste of beet top silage in 1947.

II. Comparison of Beet Top Silage and Corn Silage

Basal Ration: Grain mixture (equal weights of corn, barley and dry pulp), soybean meal, bone meal, and alfalfa.

The results of this comparison of corn silage and beet top silage are shown in Table No. 2. The corn silage ration was fed in 1944, 1945, 1946, and 1948, and the beet top silage ration in 1943, 1945, 1946 and 1948. The number of lambs per lot was either 45 or 50 during all years except 1948, when 36 were used.

During 1945, 1946, and 1948 average daily gains of lambs fed beet top silage were .38, .37, and .44 pound respectively, compared with .29, .35, and .36 pound for those fed corn silage. The differences in average daily gains in 1945 and 1948 were highly significant in favor of beet top silage.

The corn silage fed during 1945 was made from corn in the milk stage, while that fed in 1948 was of a very good quality. During 1948 beet top silage was made by ensiling the tops in a pit silo after they had been chopped

with an ensilage cutter. An excellent silage resulted from this method, and there was no waste in feeding it. The lambs consumed the silage at the rate of 5.16 pounds per lamb daily during a 71-day period, as compared with 3.00 pounds per lamb daily for those fed corn silage. The quality of the beet top silage produced in 1948, and the high daily consumption of this silage, are probable factors which account for the unusually good gains made by lambs fed beet top silage, and for the significant increase in gains over the lambs fed corn silage. The gains of the lambs fed corn silage in 1948

Table 1—Comparison of Corn Silage and Sugar Beet Top Silage. Basal Ration: Corn, Cotton seed meal, Bone meal, and Alfalfa. Scotts Bluff Substation, 1946-1947.

	Corn Silage		Beet Top Silage		Two-Year Mean	
	1946	1947	1946	1947	Corn Silage	Beet Top Silage
Number Lambs per Lot	50	45	50	45	47.5	47.5
Number Days on Feed	108	102	108	102	105.0	105.0
Average Initial Weight—pounds	59.5	70.3	59.8	71.1	64.9	65.4
Average Final Weight—pounds	96.2	105.0	97.6	103.7	100.6	100.6
Average Total Gain—pounds	36.7	34.7	37.8	32.6	35.7	35.2
Average Daily Gain, lbs., and Standard Error	.34±.01	.34±.01	.35±.01	.32±.01	.34	.335
Average Daily Silage Intake—pounds						
Corn Silage	2.01	2.35			2.25[1]	
Beet Top Silage			3.27	4.02		3.64[1]
Feed Required for 100 lbs. gain—lbs.						
Shelled corn	304.6	330.5	293.6	355.4	317.6	324.5
Cotton seed meal	74.4	72.5	71.1	77.6	73.4	74.3
Bone meal	8.4	7.9	8.2	8.3	8.2	8.2
Alfalfa	188.0	189.0	185.0	189.3	188.5	187.1
Corn silage	622.0	685.0			653.5	
Beet top silage			927.0	1254.0		1091.0
Feed Cost per 100 lbs. Gain	$14.77	$15.59	$15.56	$18.70	$15.18	$17.13
Death Loss—Number of Lambs	6	3	4	1	4.5	2.5

[1] In addition to silage the average daily ration consisted of 1.08 pounds of shelled corn, .25 pound of cotton seed meal, .03 pound of bone meal, and .64 pound of alfalfa.

were very satisfactory even though they were significantly lower than the gains obtained from beet top silage.

The daily consumption of beet top silage per lamb was higher than that of corn silage during each year the two feeds were compared. The three-year mean daily consumption of corn silage was 2.51 pounds per lamb, compared with 3.85 pounds of beet top silage. The average daily consumption of grain mixture, soybean meal, bone meal, and alfalfa (three-year mean), was 1.09, .25, .03 and .51 pounds respectively for the lambs fed corn silage; and 1.13, .25, .03 and .52 pounds for the lambs fed beet top silage.

The lambs on the beet top silage ration consumed more silage but less concentrates and alfalfa per unit of gain than those fed corn silage. The average feed cost of 100 pounds gain during the three-year period 1945, 1946

Table No. 2.—Comparison of Corn Silage and Sugar Beet Top Silage. Basal Ration: Grain Mixture[1], Soybean Meal, Bone Meal and Alfalfa Scotts Bluff Substation. Period 1943-1948.

	Corn Silage—Years Fed				Beet Top Silage—Years Fed				Three-Year Mean, 1945, 1946 and 1948	
	1944	1945	1946	1948	1943	1945	1946	1948	Corn Silage	Beet Top Silage
Number Lambs per Lot	50	45	50	36	45	45	50	36	43.7	43.7
Number Days on Feed	106	108	108	71	80	108	108	71	95.7	95.7
Average Initial Weight—lbs.	67.0	69.4	60.0	70.5	71.2	69.7	59.8	70.3	66.6	66.6
Average Final Weight—lbs.	105.9	101.1	97.8	96.4	100.0	110.9	99.8	101.7	98.4	104.1
Average Total Gain—lbs.	38.9	31.7	37.8	25.9	28.8	41.2	40.0	31.4	31.8	37.5
Average Daily Gain ,lbs., and Standard Error	.37±.01	.29±.01	.35±.01	.36±.01	.36±.01	.38[3]±.01	.37±.01	.44[3]±.01	.333	.397
Average Daily Silage Intake, lbs.										
Corn Silage	2.33	2.43	2.10	3.00					2.51	
Beet Top Silage					3.77	3.02	3.36	5.16		3.85
Lbs. Feed Required for 100 lbs. Gain										
Grain Mixture	316.0	349.0	312.3	313.6	338.0	312.0	291.2	259.0	325.0	287.4
Soybean Meal	67.0	85.0	72.0	68.4	68.0	65.0	68.4	56.7	75.1	63.4
Bone Meal	7.6	8.0	8.2	7.6	9.0	6.0	7.8	6.3	7.9	6.7
Alfalfa	152.0	174.0	172.0	112.4	211.0	130.0	166.0	107.4	152.8	134.5
Corn Silage	635.0	830.0	604.0	821.0					751.7	
Beet Top Silage					1058.0	793.0	918.0	1168.0		959.7
Feed Cost per 100 lbs. Gain	$13.37	$15.72	$13.53	$13.79	$16.10	$13.60	$14.13	$13.48	$14.35	$13.74[2]
Death Loss—Number of Lambs	0	3	2	0	1	0	3	1	1.67	1.33

[1] Equal weights of corn, barley and dry sugar beet pulp.
[2] During the four-year period for each ration the most efficient results were obtained with corn silage in 1944, and the least efficient results with beet top silage in 1943. Feed costs per 100 lbs. gain during the four-year period were $14.10 and $14.33 for corn silage and beet top silage respectively.
[3] Highly significant over average daily gain of lambs fed corn silage same year.

and 1948, was $13.74 and $14.35 for the beet top silage and corn silage rations respectively.

Neither ration appeared to influence death loss significantly. No serious digestive disturbances or scours occurred among the lambs fed either kind of silage. The maximum consumption of beet top silage at a daily rate of 5.16 pounds per lamb produced very satisfactory results.

III. Comparison of Beet Top Silage as the only Roughage, and Beet Top Silage with Alfalfa.

Basal Ration: Grain mixture (equal weights of corn, barley, and Dry sugar beet pulp), soybean meal, and bone meal.

The results of this comparison in 1943, 1945, 1946 and 1948 are shown in Table No. 3. Lambs which received beet top silage as the only roughage produced significantly lower daily gains in 1943 and 1945 than lambs fed beet top silage plus a supplement of alfalfa hay in the amount of .75 pound per lamb daily in 1943, and .49 pound per lamb daily during 1945. During 1946 and 1948 differences in average daily gains were not significant. Average daily gains during the four-year period were .36 pound for lambs fed beet top silage as the only roughage, and .39 pound for lambs fed beet top silage plus alfalfa. In addition to roughage the daily consumption of the basal ration was 1.14 pounds of grain mixture, .25 pound of soybean meal, and .03 pound of bone meal per lamb.

In this comparison during the four-year period 153.6 pounds of alfalfa saved 20.0 pounds of grain mixture, 6.3 pounds of soybean meal, 0.5 pound of bone meal, and 303.3 pounds of beet top silage in the production of each 100 pounds of gain.

Neither ration appeared to have any significant influence on the death loss of lambs.

SUMMARY

The use of beet top silage in comparison with corn silage, and the practice of supplementing a beet top silage ration with alfalfa hay, were studied at the Scotts Bluff Substation during the period 1943 to 1948.

More economical gains were obtained with corn silage than beet top silage when (1946 and 1947) each silage was fed with a ration of corn, cottonseed meal, bone meal, and alfalfa. Considerable waste of beet top silage occurred during one year of this comparison.

Higher daily gains and more economical gains were obtained with beet top silage than corn silage when (1945, 1946 and 1948) each silage was fed with a ration of grain mixture (equal weights of corn, barley and dry pulp) soybean meal, bone meal and alfalfa. During two years under this comparison (1945 and 1948) differences in mean daily gains were highly significant in favor of beet top silage. The corn silage fed in 1945 was of poor quality.

During a four-year period (1943, 1945, 1946 and 1948) the addition of alfalfa hay (0.58 pound per lamb daily) to a beet top silage ration increased daily gains and lowered the feed cost of a unit of grain. During two years

Table No. 3.—Comparison of Beet Top Silage as the Only Roughage and Beet Top Silage with Alfalfa. Basal ration fed to both lots: Grain Mixture[1], Soybean Meal, and Bone, Meal. Scotts Bluff Substation—1943, '45, '46, '48.

	Beet Top Silage as Roughage				Beet Top Silage and Alfalfa as Roughage				Four-Year Mean	
	1943	1945	1946	1948	1943	1945	1946	1948	Beet Top Silage	Beet Top Silage plus Alfalfa
Number of Lambs per Lot	45	45	50	36	45	45	50	36	44	44
Number of Days on Feed	80	108	108	71	80	108	108	71	91.8	91.8
Average Initial Weight, lbs.	71.1	69.8	60.1	70.8	71.2	69.7	59.8	70.3	67.9	67.7
Average Final Weight, lbs.	96.7	105.3	97.9	102.3	100.0	110.9	99.8	101.7	100.5	103.1
Average Total Gain, lbs.	25.6	35.5	37.8	31.5	28.8	41.2	40.0	31.4	32.6	35.4
Average Daily Gain in lbs., and Standard Error	.32±.01	.33±.02	.35±.01	.44±.01	.36±.01[2]	.38±.01[3]	.37±.01	.44±.01	.36	.39
Average Daily Roughage intake in lbs.									4.61	3.83
Beet top silage	4.72	3.99	4.12	5.63	3.77	3.02	3.36	5.16		.58
Alfalfa					.75	.49	.61	.47		
Feed Required for 100 lb. gain, lbs.										
Grain Mixture[1]	384.0	328.0	310.4	258.1	338.0	312.0	291.2	259.0	320.1	300.1
Soybean meal	76.0	79.0	71.7	56.5	68.0	65.0	68.4	56.7	70.8	64.5
Bone meal	10.0	7.0	8.0	6.3	9.0	6.0	7.8	6.3	7.8	7.3
Beet top silage	1494.0	1213.0	1173.0	1270.0	1058.0	793.0	918.0	1168.0	1287.5	984.2
Alfalfa					211.0	130.0	166.0	107.4		153.6
Feed Cost per 100 lbs. Gain	$17.48	$15.15	$14.37	$13.00	$16.10	$13.60	$14.13	$13.48	$15.00	$14.33
Death Loss—No. of Lambs	0	4	1	1	1	0	3	1	1.50	1.25

[1] Equal weights of corn, barley and dry sugar beet pulp.
[2] Significant over average daily gains of lambs which received no alfalfa in 1943.
[3] Highly significant over average daily gains of lambs which received no alfalfa in 1945.

(1943 and 1945) daily gains were significantly higher as a result of adding alfalfa hay to the ration.

The average daily consumption of beet top silage was higher than corn silage. Lambs consumed beet top silage at a maximum daily rate of 5.16 pounds in addition to a basal ration with excellent results.

Neither beet top silage nor corn silage appeared to influence death loss significantly.

No serious digestive disturbances or excessive trouble with scours occurred during the use of either of the two kinds of silage.

The quality of silage used was an important factor influencing the results obtained in these tests.

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Observations on Utilization of Sugar Beet Tops by Livestock

E. J. MAYNARD[1]

Sugar beet tops are still fed principally to the ruminants—dairy cattle, beef cattle and sheep—and less frequently to horses and to brood sows. These beet tops have generally been fed in the form of fresh green tops, wilted tops, so-called "field-cured" dried tops or beet top silage. In practically all instances, beet tops have included the crown of the beet (which has more recently varied considerably in size depending on the method of harvesting) as well as the leaves and stems.

In the western irrigated areas of the United States a large share of the beet tops produced are still being pastured in the field with beef cattle or sheep during a period of several months after the beets have been harvested, although in recent years there has been a growing tendency to ensile green or wilted tops, or to stack the field-cured dried tops to be hand-fed as a portion of the growing or fattening ration.

It has been difficult to determine and establish any accurate constant feed value for beet tops in general when harvested in these various forms due to several variable factors, including the weight relationship of tops to beets and leaves to crown, moisture content and amount of exposure to the elements. In other words, beet tops handled as they have been can vary between wide limits in their feeding value.

The facts have been well established, however, that beet tops provide a valuable livestock feed; that they contain both growth and energy producing nutrients of high quality; that they are highly palatable and that, at prevailing price relationships to standard livestock feeds, they have reduced livestock feeding costs materially.

Since beet tops are often included as an integral part of rations for livestock, a dependable table to indicate their digestible nutrient content at various moisture levels has been needed to better evaluate the kind and amount of tops used. Several years ago the author assembled available data from western agricultural experiment stations to determine the amounts of grain and alfalfa hay which could be saved or replaced by the field-cured dried beet tops produced from an average ton of harvested beets.

A resume of 27 separate feeding tests with cattle and sheep indicated that the field-cured dried tops produced from an average ton of harvested beets had saved or replaced on the average 46 pounds of corn plus 150 pounds of alfalfa hay in producing gains in weight equal to those produced with grain and hay alone. As the weight of dry substance in these tops and crowns produced from a ton of beets amounted to approximately 10% of

[1] General Livestock Consultant, The Great Western Sugar Company.

the weight of the harvested beets, or 200 pounds, it was assumed that the total digestible nutrients contained in these amounts of replaced grain and hay should represent the approximate amount of total digestible nutrients available in this 200 pounds of dry substance of the beet tops. According to Morrison's figures on the average digestible nutrients in feeds this amounts to 18.8 pounds of digestible protein and 112.3 pounds of total digestible nutrients for the 46 pounds of corn plus 150 pounds of alfalfa hay or, in other words, the dry substance of field-cured beet tops was credited with a digestible protein content of 9.4% and a total digestible nutrient content of 56.2%.

In his recently published 21st edition of "Feeds and Feeding," Morrison reports the following average analysis for 86 samples of green beet tops: dry matter 17.8%, digestible protein 1.7%, total digestible nutrients 10.4%. On a dry substance basis this amounts to 9.6% digestible protein and 58.4% total digestible nutrients.

With a small allowance for field losses this comparison then would seem to substantiate a replacement value equal to 46 pounds of corn plus 150 pounds of alfalfa hay for the dried tops produced from an average ton of beets.

By using a graduated moisture content table based on Morrison's figures for green or wilted tops and on the figures derived from these replacement values for dried tops, a fairly close estimate of tops values in the livestock ration is possible.

Table 1.—Pounds of Digestible Nutrients in One Pound of Feed.

		Digestible Nutrients	
	Dry Substance	Protein	Total
Sugar beet tops—green	.178	.017	.104
Sugar beet tops—green	.20	.019	.117
Sugar beet tops—wilted	.30	.029	.175
Sugar beet tops—wilted	.40	.038	.234
Sugar beet tops—dried	.50	.048	.281
Sugar beet tops—dried	.60	.058	.338
Sugar beet tops—dried	.70	.067	.394
Sugar beet tops—dried	1.00	.096	.562

The nutritive ratio, or ratio of digestible protein to digestible carbohydrate equivalent, is 1:5.1 for beet tops.

Incidentally, these feed replacement values for beet tops expressed in terms of grain and hay provide a ready method for determining the money value of tops based on current prices for these other feeds. For instance, with corn priced at $1.35 per bushel or $2.41 per cwt., and with alfalfa hay priced at $18.00 per ton, the dried tops produced from a ton of beets would be worth $2.46. While it may not be conceivable that dried beet tops might command this figure, it would nevertheless hold that they would be worth this amount to the grower who could preserve them properly and use them in his own feeding operations where their protein value might be realized.

The next question concerns the relative value of beet tops in the form of beet top silage. Here again there are variable factors involved. However, those who have fed beet top silage in proper amounts to beef cattle, dairy cattle, sheep or lambs have found it to be a palatable, succulent feed fully equal, pound for pound, to good corn silage in feeding value. Beet top silage has been used extensively in rations fed dairy cattle and lambs at the Scottsbluff sub-station of the Nebraska Agricultural Experiment Station during the past decade.

Lionel Harris, superintendent of this Station, has stated that the tops produced from sugar beets grown in a manured rotation with alfalfa hay will produce approximately 1,000 pounds of edible beet top silage per ton of beets harvested and that this beet top silage has proved to be fully equal, pound for pound, to corn silage produced from 100-bushel corn.

Available information coupled with extensive observations would seem to indicate the superiority of beet top silage over other forms in which tops are fed, provided that the harvesting and ensiling of the tops can be handled efficiently with suitable farm machinery.

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